A COMPARISON OF DIFFERENT METHODS OF ROUTINE SOIL ANALYSIS

P. A. Gallagher, P. F. Ryan and J. C. Brogan

An Foras Taluntais, Soils Division, Johnstown Castle, Co. Wexford.

ABSTRACT

The method of soil analysis used here for large scale soil testing (Morgan's method, modified by Peech and English (1)) compared very favourably with other well known methods when comparisons were made on a broad general basis. However, further work is required to study the relative values of different methods to obtain more precision with reference to local variations such as soil type, together with physical and chemical soil properties.

INTRODUCTION

A national soil testing service, for the benefit of advisory officers, was established at Johnstown Castle in 1948. Morgan's method as modified by Peech and English (1) was selected as the most suitable method of analysis, not only because some limited experience of its use had previously been obtained in Ireland, but also because its simplicity permitted the employment of time saving techniques. The popularity of the soil testing service was shown by the rapid increase in the number of samples tested, from 5,000 in 1948 to a total of about 100,000 each year since 1953.

The purpose of a chemical soil test is to forecast as accurately as possible the nutrient-supplying capacity of the soil for crops. The accuracy is assessed by correlation of crop response to applied fertiliser with nutrient levels shown by the method of soil analysis used.

Such correlation studies take several years to carry out, and therefore the evaluation of soil analysis in Ireland initially, had necessarily to be based on the results of studies carried out abroad, and on the limited experience obtained, before the service was introduced generally in this country.

The widespread use of the soil analysis service showed the necessity of checking whether Morgan's was the most suitable method of analysis for Irish soils. Accordingly, a preliminary series of field experiments on crop response and nutrient status was commenced in 1950 and continued for a number of years. The crops included potatoes, roots, wheat, oats, barley and sugar beet and the effects of both phosphorus and potassium were studied. The present paper is a preliminary report on these studies with oats, potatoes, and swedes. An NPK factorial experiment on sugar beet, commenced in 1959, was also included in the study.

EXPERIMENTAL

1. *Field Methods*

The field studies on potatoes, swedes and cereals were carried out at many centres on a variety of soil types by Agricultural Instructors. A simple experimental design, with single or duplicated randomised treatments, was adopted. The correlation studies on sugar beet were done on samples from comprehensive NPK fertiliser factorial trials begun in cooperation with Comhlucht Siuicre Eireann, Teo. (the Irish Sugar Company) in 1959.

In all cases an adequate base dressing of the nutrients not under test was applied. Details of the treatments used are as follows:—

Oats: Conducted at 68 centres (1952, 1953). Phosphorus series were, control, 1, 2 and 4 cwt. superphosphate (7 per cent P) per acre. Potassium series were, control, ½, 1 and 2 cwt. muriate of potash (42 per cent K) per acre.

Potatoes: Conducted at 70 centres (1951, 1952). Phosphorus series were, control, 3 and 6 cwt. superphosphate (7 per cent P) per acre. Potassium series were, control, 1½ and 3 cwt. muriate of potash (42 per cent K) per acre.

Swedes: Conducted at 48 centres (1950, 1951). Phosphorus series were, control, 3 and 6 cwt. superphosphate (7 per cent P) per acre. Potassium series were, control, 2 and 4 cwt. muriate of potash (42 per cent K) per acre.

Sugar Beet: Conducted at 16 centres in 1959. An NPK factorial (3 x 3 x 3) design, with four replications was adopted. Nitrogen treatments used were control, 60 and 120 lb. of nitrogen per acre. The phosphorus series consisted of control, 40 and 80 lb. phosphorus per acre. The potassium series comprised control, 120 and 240 lb. potassium per acre. Before the trial was laid down, two composite surface samples were taken from each experimental area.

2. *Laboratory Methods*

Soil samples from the different experiments were subjected to six internationally known methods of analysis:—(a) Morgan's method, as modified by Peech and English (1) which involves extraction with acetic acid buffered with 10 per cent sodium acetate to pH 4.80; (b) Olson's method for phosphorus (2) featuring extraction with 0.05 normal sodium bicarbonate at pH 8.5; (c) the P_1 method of Bray and Kurtz (3) for phosphorus, extracting with 0.03 normal ammonium fluoride and 0.025 normal hydrochloric acid; (d) the P_2 method of Bray and Kurtz (4) for phosphorus, extracting with 0.03 normal ammonium fluoride and 0.1 normal hydrochloric acid; (e) Truogs' method (5) for phosphorus and potassium, using 0.002 normal sulphuric acid buffered with ammonium sulphate to pH 3.0, and (f) the lactate acetate method of Egner for phosphorus and potassium as modified by Riehm (6).

3. *Mathematical Methods*

The results of the experiments were assessed by use of the simple correlation Co-efficient (r). The statistics used to establish this relationship were percentage yield

and log. soil test value. The percentage yield concept of Bray (8) is defined as:—

$$\frac{\text{Yield without fertiliser x 100}}{\text{Yield with adequate fertiliser}}$$

Percentage yield was assumed to follow the Mitscherlich growth curve, over the full range of soil nutrients. By conversion of this logarithmic function into a linear curve, correlation coefficients have been established between percentage yield and log. soil test value. Percentage yield figures used in the correlation studies of the oats, potatoes, and swedes trials were done on the treatments which received the heaviest application of fertiliser in each case. The response from the other increments were used on another study (9) to assess the most profitable level of fertiliser for each crop. In the sugar beet trials, however, analysis of the factorial design indicated that at the rates of nitrogen used, especially when the levels of P and/or K were low, significant negative interactions occurred and yields were depressed. The use of "simple effects" was therefore precluded and consequently it was decided to evaluate yield differential by the use of "main effects" got from the analysis of the factorial design.

RESULTS

Phosphorus

The relative mean values of the different methods in forecasting response to applied phosphorus, is shown by the correlation coefficients presented in Table I. All

TABLE I

Correlation coefficients between crop response and soil nutrient status (using different extraction methods)

Crop	Year	No. of experi-ments	Extraction Method					
			Morgan	Egner-Riehm	Truog	Olson	Bray P_1	Bray P_2
Potatoes	1950, 1951	70	0.56**	0.57**	0.57**	0.38**	0.34**	0.49**
Swedes	1950, 1951	48	0.71**	0.59**	0.67**	0.47**	0.41**	0.52**
Oats	1952, 1953	68	0.22	0.38**	0.37**	0.35**	0.48**	0.51**
Sugar Beet	1959	15	0.82**	0.70**	0.67**	0.56**	0.36	0.61*

* = significant ** = highly significant.

methods gave highly significant results with potatoes. Highest correlations were given by the methods of Morgan, Egner-Riehm and Truog, there being no significant difference between the methods. Correlations followed a similar pattern in the case

of swedes, but Morgan's gave the best results. In the case of oats, however, all correlations were significant except Morgan's, where a very low coefficient of 0.22 was obtained. Results for sugar beet showed a very high degree of accuracy, with Morgan's giving a coefficient of 0.82.

Segregation of the data from the different experimental centres on the basis of different categories of parent material and pH showed no consistent relationship between these categories and nutrient status/crop response data.

Potassium

Correlation coefficients for the methods of Morgan, Egner-Riehm and Truog relating potassium levels to crop response from applied fertiliser, are shown in Table II. Oats was not included in this study but the results for potatoes, swedes and sugar beet showed that all three methods were highly accurate, Morgan's giving the highest correlation figures for all crops. Sugar beet again gave the highest correlation coefficient, 0.79, similar to results with phosphorus.

TABLE II

Correlation coefficients for crop response to applied potassium and soil potassium level (using different extraction methods)

Crop	Year	No. of experiments	Extraction Method		
			Morgan	Egner-Riehm	Truog
Potatoes	1950, 1951	70	0.63	0.53	0.60
Swedes	1952, 1953	48	0.55	0.52	0.51
Sugar Beet	1959	15	0.79	0.74	0.71

All figures highly significant.

DISCUSSION

The data presented are mean results from a relatively large number of experiments, and the correlations established apply only on a general basis to the whole country. Individual centres showed discrepancies and variations not apparent from the mean results. These variations were obviously due to the influence of local factors such as soil type and climate. The failure of Morgan's method with phosphorus on oats reported above, was probably due to soil physical or chemical factors which were not considered in this preliminary study, in which methods of analysis were related to yield responses only.

Further work on soil test correlation studies is needed to determine the influence on the accuracy of various methods of analysis, of soil type and such measurable soil characters as pH, organic matter, texture, drainage and parent material. The lower levels of correlation obtained in the oats, potatoes, and swede trials and the higher values obtained from the sugar beet trials was undoubtedly related to the more precise method of field experimentation used in the latter case. A high degree of variance can be expected from the low level of replication used in the former experiments. Fewer experiments carried out in a more elaborate layout, located in areas representing widely distributed soil groups would seem to be indicated.

Other workers have successfully followed this procedure. Thus, Baumgardner and Barber (10) obtained a very high degree of soil test accuracy by relating correlation data to soil type, as established by a soil survey. Furthermore, Williams (11) found that methods of soil analysis were correlated with differences in the parent material of soils; and Lawton (12) reported improved correlation on the basis of subdivision into different categories of texture and drainage. Bishop and Barber (13) obtained very good results from a study of the influence of a relatively large number of soil physical and chemical parameters, involving the use of multiple correlation coefficients.

ACKNOWLEDGEMENTS

Grateful acknowledgement is due to the numerous Agricultural Instructors, who carried out the field trials, to Mr. J. Parle for some of the analyses and compilation of the data, and to Mr. F. W. O'Keeffe for the statistical analyses.

REFERENCES

1. Peech, M. and English, L., *Soil Sci.*, **57**: 167, 1944.
2. Olson, S. R., Cole, C. B., Watanabe, F. S. and Dean, L. A., *U.S. Dept. Agr. Circular*, 939, 1954.
3. Bray, R. H. and Kurtz, L. J., *Soil Sci.*, **59**: 39, 1945.
4. Bray, R. H., "*Diagnostic Techniques for Soils and Crops*," American Potash Institute, 53-86.
5. Truog, E., *J. Am. Soc. Agron.*, **22**: 874, 1930.
6. Egner, H. and Riehm, H. (Private communication).
7. Black, C., *Soil Sci.*, **87**: 100, 1959.
8. Bray, R. H., *ibid.*, **58**: 305, 1944.
9. Walsh, T., Ryan, P. F. and Kilroy, J., *J. Stat. and Soc. Inquiry*, 104, 1958.
10. Baumgardner, M. F. and Barber, S. A., *Soil Sci.*, **82**: 409, 1956.
11. Williams, E. G., *Trans. Int. Soc. Soil Sci., Comm. II and IV* (Dublin 1952), **11**: 84-91.
12. Lawton, K., *Proc. Soil Sci. Soc. America*, **12**: 379, 1947.
13. Bishop, W. D. and Barber, S. A., *ibid.*, **22**: 435, 1958.

THE EFFECT OF CEREAL ROOT EELWORM (*Heterodera major*, O. Schmidt) ON ITS HOSTS

J. J. Duggan

An Foras Taluntais (Agricultural Institute), Nematology Department, University College Experimental Farm, Dublin 9

ABSTRACT

Studies were made (on field and microplot scale) on the effect of cereal root eelworm on varieties of oats, wheat and barley and on four economically important grasses. Symptoms of eelworm attack on the different crops are described and the effect of different levels of infestation are tabulated. Oats was found to be more susceptible to attack than wheat or barley and differences in varietal reaction were noted in the latter. Crop failures due to cereal root eelworm attack were recorded with all three cereals. Three cases of failure in ryegrass and cocksfoot were also recorded.

INTRODUCTION

While carrying out population studies on cereal root eelworm (1) observations were made on the effect of the parasite on its various hosts and on different varieties of the same host. As different initial levels of infestation were used in these studies it was possible, also, to observe the effect of varying degrees of infestation on the host crops. Studies were also made on affected crops in the field in different areas and soil types.

Symptoms of H. major *attack*

The appearance of patches is usually the first evidence of the presence of the eelworm in an oat crop. On closer examination, these patches are found to be composed of weak stunted plants which appear to have stopped growing. In a heavily infested crop this patchiness becomes very pronounced towards the end of May (Fig. 1) and the weak plants fail to recover and become choked with weeds. The degree of stunting and growth retardation is illustrated (Fig. 2). Three to four weeks after the young plants have appeared above ground the oldest leaf assumes a characteristic brick-red colour. This discolouration starts at the tip of the leaf and works its way downwards until the whole leaf becomes affected and dies. The second leaf becomes similarly affected. The discolouration may vary somewhat according to the mineral status of the soil, and lasts for varying periods. Affected leaves generally die off by the end of June when fresh ones are produced. The recovery of the plants depends on the severity of the attack, and if the level of infestation is sufficiently high they do not recover

(Tables I and II). Often, heavily infested plants do not die off completely but remain stunted and form ears prematurely. Such plants may be found bearing a few poorly-filled ears when four to eight inches high in bad patches in a field.

Patchiness is usually the first evidence of the presence of cereal root eelworm in wheat and barley also. While the leaves of infested wheat plants were, on occasions, found showing the typical brick-red discolouration symptoms described above, they more usually assume a sickly yellowish colour. The parasite invariably causes a yellowing of barley leaves which becomes evident in early May.

Yellow-dwarf virus, a cereal disease caused by an aphid-transmissable virus, also causes a reddish discolouration in oat leaves. Since this disease has been found occurring in different parts of the country in recent years its symptoms might be confused with those caused by eelworm attack. However, the discolouration caused by the virus occurs on later emerging leaves as well as on those which are first formed. Moreover, according to Oswald and Houston (2) blasting of the flower parts is an additional and consistent symptom of yellow-dwarf in oats. *H. major* does not cause any direct damage of this nature to the flower-heads although ears may be poorly filled as a result of the attack on the root system of the plant.

Effect of time of sowing and weather conditions on host-parasite relationship

The effect of time of sowing on host-parasite relationship was studied on a field and microplot scale. Winter-sown oats grew normally and showed no symptoms of attack until the following May. The winter-wheat varieties "Glasnevin Rosa" and "Capelle Desprez," when sown in winter in infested soil, showed no symptoms of eelworm attack and yielded a full crop. The same varieties were severely attacked and showed symptoms of heavy eelworm infestation when sown in portions of the same soil in spring. It was also found that oats sown in a heavily infested field late in June was not affected by the parasite whereas oats sown in parts of the same field in April bore acute symptoms of eelworm attack.

These differences in host-reaction may be explained by the seasonal variation in the activity of the parasite. It was found that cereal root eelworm was most active and invaded the roots of host plants in greatest numbers between the end of March and the middle of May (3). There was a falling off in root invasion in June and this decrease became more evident in July. Small numbers of larvae invaded the roots in August and September. From October to February root-invasion did not occur to any appreciable extent due presumably to winter dormancy.

Observations made over a number of years showed that the host-parasite relationship may also be affected by weather conditions. When a cold dry period preceded and immediately followed the sowing of the crop, the activity of the eelworm appeared to be curtailed. It has been found that during such a period eelworm attack is not as severe as the initial level of infestation would lead one to expect. Presumably, the drying out of the top layers of soil limits the activity of the eelworm, and plants become established before mass invasion of the roots occurs. Cases of severest damage

by the parasite have been found to coincide with high rainfall in April and May. When a droughty period occurs later in the season parasitised plants are much more affected by the drought than are normal healthy ones.

Effect on the root system of the plant

The roots of infested plants (oats, wheat and barley) become characteristically deformed. If an infested plant is eased gently out of the soil the roots are found to be shorter than normal and where a worm is developing a slight swelling is found. Invasion by the parasite causes the plant to throw out numerous side-roots and if these in turn are invaded, further side-roots are produced. Thus, infested roots are short and abnormally branched when compared with the roots of a healthy plant.

Towards the middle of June the female worms can be seen as white cysts on the roots of infested plants. These cysts tend to become easily detached from the roots and are, therefore, sometimes difficult to find. As Franklin (4) points out, cereal root eelworm differs from beet eelworm in this respect since the cysts of the latter species remain comparatively firmly attached to the roots of the host plant for a longer period.

H. major *infestation and manganese deficiency in oats*

In dry periods infested plants were found to be more susceptible than healthy plants to manganese deficiency. There is no suggestion of a direct relationship between the intensity of eelworm infestation and the supply of available manganese in the soil but it may be assumed that because of their unhealthy root system, parasitised plants are more prone to this deficiency in a dry spell. It was also found that plants suffering from both severe eelworm attack and manganese deficiency did not respond as well as less-severely attacked and non-infested plants (also suffering from manganese deficiency) when sprayed with 1 and 2 per cent solutions of manganese sulphate.

Effect of nitrogenous fertiliser on infested oat plants

Application of a top dressing of nitrogen as sulphate of ammonia or nitro-chalk on infested crops caused no marked improvement in growth or increase in yield. Both fertilisers were applied at rates of 0.5, 1 and 2 cwt. per statute acre in different centres. Although the applications caused plants to assume a greener and more healthy appearance, the over-all result was the production of a copious crop of weeds which choked out the weak stunted plants in badly infested patches in the field.

The effect of different levels of infestation on oats, wheat and barley

While damage ranging from slight patchiness to complete crop-failure has been recorded in oats, wheat and barley, both microplot and field studies showed that oats was more susceptible to severe damage than the other host crops. Population levels which were capable of causing a reduction of only 20 per cent in barley yield caused a complete failure in oats.

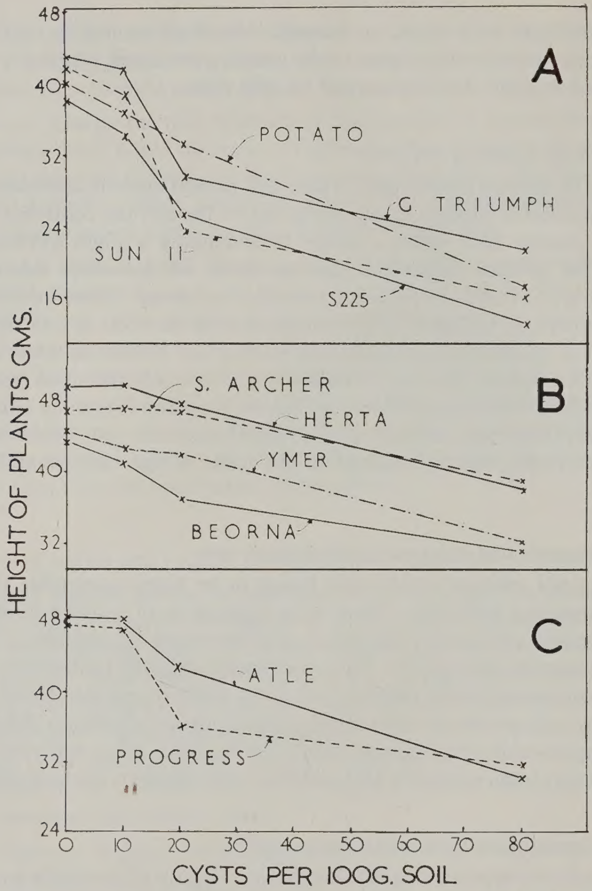


Fig. 3—Effect of increasing levels of infestation on growth of varieties of (A) oats, (B) barley and (C) wheat.

In preliminary experiments different varieties of each cereal were sown in plots containing infested soil. There were three series of plots and the degree of infestation (cysts per g. of air-dried soil) in each series was as follows:—Series 1, 0.8; Series 2, 0.2; and Series 3, 0.1. The heights of the plants in each plot were measured on June 15 by placing a metre-scale vertically against each plant and holding the plant to its maximum height which was then read off the scale. From these measurements, the mean plant height for each plot was calculated and the mean growth which plants had made at each infestation level was plotted.

These growth curves (Figure 3) illustrate the marked reduction in plant growth with increased eelworm infestation. The marked difference in the slope of the

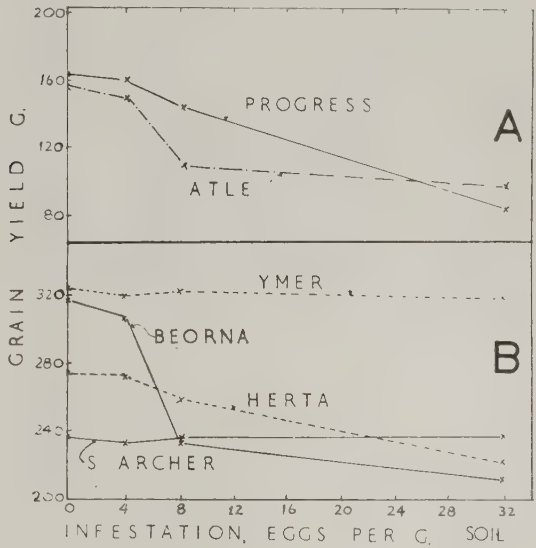


Fig. 4—Effect of increasing levels of infestation on grain yields of varieties of (A) wheat, and (B) barley.

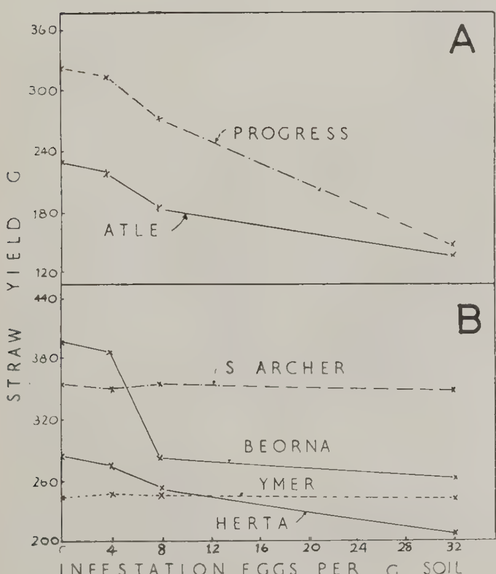


Fig. 5—Effect of increasing levels of infestation on straw yields of varieties of (A) wheat and (B) barley.

curves for oats and wheat compared with that for barley shows the greater effect of the eelworm on the two former crops. The lowest degree of infestation did not significantly effect the growth of the barley plants. Moreover, the curves for the oat and wheat varieties slope sharply when the degree of infestation increases from 0.1 to 0.2 cysts per g., whereas with the barley varieties (with the exception of "Beorna") the slope of the curve between these two degrees of infestation is not marked. While barley proved to be the least affected of the three cereals, its susceptibility to eelworm attack is, nevertheless, clearly demonstrated in these growth curves.

When crops from more recent microplot experiments (1) were harvested, the grain and straw yields from each plot were estimated and the figures obtained were plotted against the degree of infestation. These yield curves are shown (Figs. 4, 5, 6).

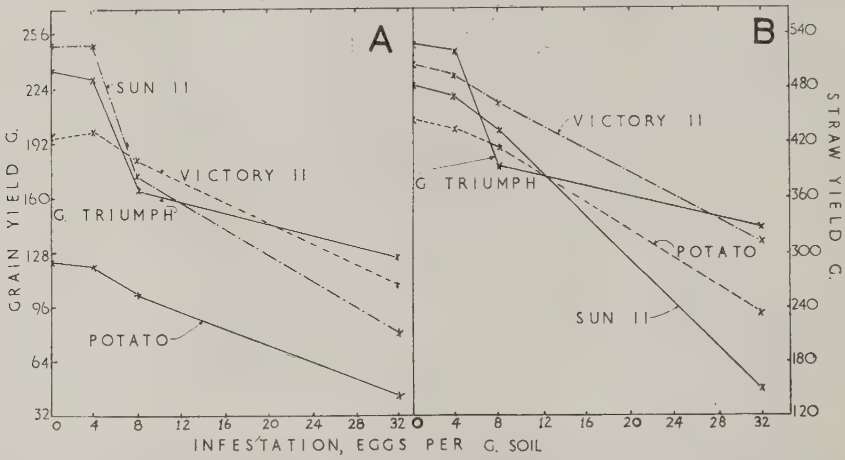


Fig. 6 Effect of increasing levels of infestation on (A) grain yield, and (B) straw yield of varieties of oats.

It can be seen that, in the case of oats and wheat, there was a marked reduction in the yields of grain and straw with increased eelworm infestation. In the case of the barley varieties there was a marked difference between the curves obtained for "Ymer" and "Spratt Archer," and those for "Herta" and "Beorna." The two former varieties recovered and "grew away" from the early symptoms of eelworm attack and yields were not much affected by increased eelworm infestation. These results indicate that infestation levels as high as 32 eggs per g. would not affect the yielding capacity of these two barley varieties. The vaiiety "Beorna," and to a lesser extent, the variety "Herta" showed significant reductions in grain and straw yields when the degree of infestation increased from 4 to 8 and to 32 eggs per g. In these experiments, "Beorna" was by far the most susceptible barley variety.

The population levels which can cause severe damage to cereals, particularly oats and wheat, are relatively low when compared with the level of *H. rostochiensis* populations necessary to cause damage to potatoes. Carroll and McMahon (5) found that

TABLE I

Effect of different levels of infestation on oats, wheat and barley

Degree of infestation, cysts per 100 g. soil	Effect on oats	Effect on wheat	Effect on barley
5	Slight discolouration of first leaves. No obvious stunting of plants or patchiness in crop. No effect on yield.	No symptoms. Yield not affected.	No symptoms. Yield not affected.
10	First leaves typically discoloured. Evidence of growth retardation in June. Plants recovered well as season advanced. Yield reduced by 10-20 per cent.	First leaves discoloured. Slight unevenness in plant growth and yield reduced by about 3 per cent. Probably not noticeable on a field scale.	Slight discolouration in Herta and Beorna. Yield of Beorna reduced by twenty per cent. Yield of other varieties not affected.
20	Severe discolouration of plants in June, patchiness. Yield reduced as much as 35 per cent in some cases.	First leaves severely discoloured. Evidence of growth retardation in June. Plants made recovery as season advanced but yield reduced by 20 per cent.	All varieties showed yellowish discolouration, was most pronounced in Beorna. Yields of Beorna and Herta reduced. No significant effect on yields of Ymer and Spratt Archer.
40	Crop failure.	Patchy crop. Yield reduced by 30-40 per cent.	Severe discolouration of first leaves in all varieties in June. Plants recovered well, but yields of Beorna and Herta reduced by 35 and 25 per cent respectively.
60	Crop failure.	Very patchy crop. Yield reduced by 50 per cent.	Severe discolouration of all varieties tested. Ymer recovered to yield a good crop. Beorna and Herta remained patchy. Spratt Archer not tested at this level of infection.
80	Crop failure.	Crop failure.	Beorna and Herta partial failures. Ymer and Spratt Archer very patchy, yield reduced as much as 40 per cent.

TABLE II

Effect of different levels of infestation on oats, wheat and barley

Degree of infection, eggs per g. soil	Effect on oats	Effect on wheat	Effect on barley
4	Slight discolouration of first leaves. No obvious stunting of plants of patchiness in crop. No significant effect on yield.	No symptoms. Yield not affected.	No symptoms. Yield not affected.
8	First leaves of young plants typically discoloured. Evidence of growth retardation and slight patchiness in June. Plants made good recovery, but yields reduced as follows: Glasnevin Triumph 30, Sun II 32, Potato 14 and Victory 10 per cent.	First leaves of young plants discoloured. Slight uneveness in plant growth. Yield reduced by 7 per cent. Probably not noticeable on a field scale.	Herta and Beorna discoloured in early stages of growth. Yield of Beorna reduced by 25 per cent. Yield of Herta slightly reduced, probably not noticeable on a field scale. Ymer and Spratt Archer not affected.
32	Crop a partial failure. Severe patchiness. Yield reductions (microplot scale) were: Glasnevin Triumph 52, Sun II 70, Potato 64 and Victory II 47 per cent.	Atle and Progress tested. Both very patchy. Yield reductions (microplot scale) were: Atle 44, Progress 50 per cent.	First leaves of all four varieties discoloured. Growth retardation in June very obvious in Herta and Beorna, and yields were reduced as follows: Herta 23, Beorna 34 per cent. Ymer and Spratt Archer "grew away" from early symptoms of attack and yields were not affected.

about four cysts of potato root eelworm per cc. of soil could give rise to potato sickness in its most severe form. In the case of cereal root eelworm, an infestation level of 40 cysts per 100 ccs. of soil was found by the writer to be sufficiently high to cause severe damage to oats and wheat and some varieties of barley. The effects of different degrees of infestation on oat, wheat and barley varieties are shown (Tables I and II).

While many instances of varying degrees of damage to crops have been observed in the field, the presence of the eelworm in such fields did not come to the writer's notice until the damage became apparent in the crop. At that stage it was not possible to estimate the initial level of infestation. The data given (Tables I and II) are therefore based mainly on microplot observations. It could be argued that the effect of the eelworm was accentuated by concentrating plant roots and eelworms within the confines of a plot. However, the size of the plots (3 x 1 ft. and 6 x 4 ft.) and the fact that they were open at the bottom and resting on the sub-soil of the site made this less likely to happen than if pots were used. It is quite possible, on the other hand, that the various degrees of infestation given in the tables would cause even more serious damage on a field scale, since plants in the microplots are subjected to more individual care than are plants in the field (e.g. watering, placement of fertilisers, lack of competition with weeds, etc.). It is important that these points be borne in mind when extrapolating, from the tables, about what might happen on a field scale where different conditions obtain.

Effect of H. major *on some economically important grasses*

Cereal root eelworm is capable of causing severe damage to some of the economically important grasses. Such damage has been observed on a field scale and in microplots. In a field in Co. Kilkenny in which the degree of infestation was 1 cyst per g. of soil, and in which oats had failed the previous year, the following grass mixture was sown in the spring of 1953 (lb. per acre):—perennial ryegrass 12, Italian ryegrass 5, cocksfoot 8, clover (S100) 2, and New Zealand wild white clover 1. A dressing of 3 cwt. of superphosphate, 1 cwt. muriate of potash and 1 cwt. of ammonium sulphate was applied at sowing time. The seeds germinated satisfactorily, but the young grass plants assumed a staring appearance and seemed to stop growing. A dressing of 1 cwt. of sulphate of ammonia was applied again, in August, and a complete dressing similar to that applied at sowing time was put on in the spring of 1954. Despite this manuring, the cocksfoot died out completely and the ryegrass thinned out considerably. The pasture eventually developed into a clover sward.

Two cases were recorded in Co. Galway, where difficulty was experienced in procuring the establishment of ryegrass-cocksfoot-clover mixtures which were sown in heavily infested soil. Since the fertiliser requirements of the plants were adequately catered for and seeing that a similar grass mixture fared quite well and grew normally in neighbouring fields which were not infested, the poor performance of the ryegrass and cocksfoot may be attributed to *H. major* attack. In these two instances, also, the pastures developed into a clover sward.

On a few occasions, the writer has observed a reddish discolouration on infested perennial ryegrass plants. The more general symptoms of attacks, however, were the

unthrifty staring appearance of heavily infested plants and their failure to tiller and spread normally. The effect of different degrees of infestation on meadow fescue, perennial ryegrass and on Italian ryegrass is shown in Fig. 7.

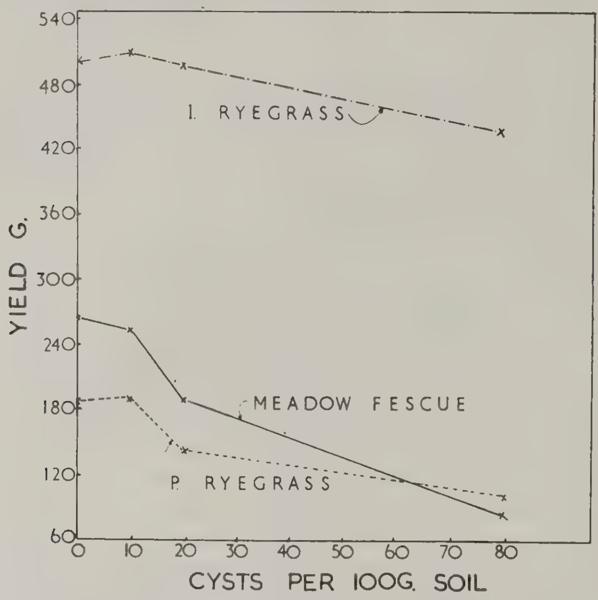


Fig. 7—Effect of increasing levels of infestation on yields of three grasses.

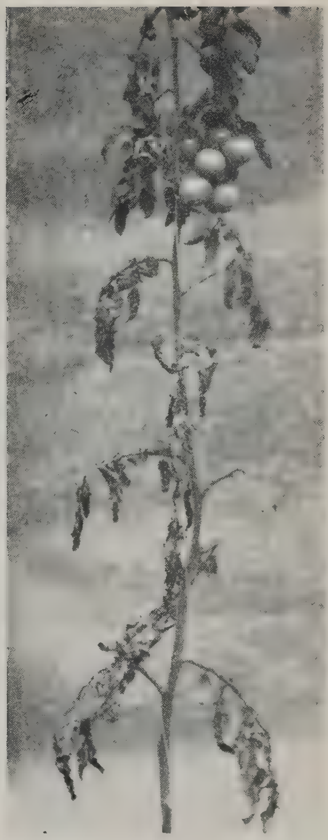
The grasses were sown, in spring, in plots containing different degrees of infestation. The following autumn, the grass in each plot was cut back to within an inch of the soil-level and the cut material was oven-dried and weighed, thus giving the grass-yields for each plot. These yield-figures were plotted against the degree of infestation and the curves illustrate the marked reduction in grass-production with increased eelworm infestation. Perennial ryegrass and meadow fescue appeared to be more severely affected than Italian ryegrass, as evidenced by the more sharply diverging curves for the two former grasses. It was not possible, because of an accident, to estimate the cocksfoot yields, but it was observed that this grass was as severely affected as perennial ryegrass and meadow fescue by high levels of infestation.

REFERENCES

1. Duggan, J. J., *Econ. Proc. R. Dublin Soc.*, **4 (6)**: 103, 1958.
2. Oswald, J. W. and Houston, B. R., *Phytopathology*, **43 (3)**: 128.
3. Duggan, J. J., *Sci. Proc. R. Dublin Soc., Ser. B.*, **1 (3)**: 21, 1961.
4. Franklin, M. T., "The Cyst-forming Species of *Heterodera*," Commonwealth Agric. Bur., 1951.
5. Carroll, J. and McMahon, E., *J. Helminth.*, **13 (2)**: 77, 1935.

(Above) Fig. 1 — Heavily infested patch in oat crop.

(Left) Fig. 2 — Plants from (right) heavily infested, and (left) lightly infested patches of an oat crop.



(Left) Fig. 1 — Tomato leaf showing partial necrosis due to manganese toxicity.

(Right) Fig. 2 — Tomato plant severely affected by manganese toxicity. Note necrotic foliage and failure of many trusses to set fruit.

A CASE OF MANGANESE TOXICITY AFFECTING A COLD HOUSE TOMATO CROP

J. G. D. Lamb

An Foras Taluntais, Johnstown Castle Agricultural College, Wexford

ABSTRACT

A case is described of manganese toxicity affecting tomato "Ware Cross" grown on an acid soil never treated with steam or heat. The leaves most affected were those near the fourth and fifth fruit trusses. These leaves showed a slight but distinct interveinal chlorosis, followed very rapidly by necrosis of all or some of the leaflets of the affected leaves. Associated with the condition was a failure of the fourth and fifth trusses to set fruit. Plants which had received heavy dressings of phosphate fertiliser were less affected. Tissue analysis confirmed that the affected plants had a very high content of manganese in the foliage, those grown with the high phosphate dressing showing a lower content.

INTRODUCTION

The danger of excess of soluble manganese being released by the heating of acid soils is widely known. For instance, Lawrence (1) has stressed the unsuitability of acid loams (pH 4.0-5.0) in making up the John Innes seed and potting composts for this reason. Otherwise manganese toxicity is not usually regarded as a problem in the culture of glasshouse crops, for, quite apart from the fact that commercial growers are aware of the dangers of steaming acid soils, very acid soils are rare under the normal cultural methods practised under glass in Ireland. This was apparent, for instance, in a countrywide survey of glasshouse soils published recently (2) which showed that glasshouse soils were usually alkaline and also that available phosphates tended to become very high, thereby reducing the danger of manganese toxicity.

This paper describes a case of manganese toxicity which occurred in a crop of cold house tomatoes, grown in a soil that had never been steamed. It was considered advisable, therefore, to describe the symptoms and the circumstances under which they arose, for similar conditions could occur elsewhere and damage to the crop ensue before the symptoms were recognised.

For two seasons satisfactory crops of tomato, variety Ware Cross, had been raised in the house before the symptoms were noticed during the third season (1959). The plants, raised in the usual manner in the John Innes composts, were planted out in April 1959. By mid July a severe necrotic condition of the leaves was widespread through the house. Detailed examination of the plants showed that the following symptoms were characteristic of the disease.

All the plants carried foliage of a lustreless ashy grey tinge, this tinge being less pronounced on the youngest leaves. The older leaves showed a slight but distinct interveinal chlorosis, giving a marbled effect and the leaflets curled downwards. This was followed by sudden necrosis of the laminae, usually affecting the apical leaflets first, but not invariably so. Large interveinal necrotic spots developed with such rapidity that the whole lamina was often dead before the onset of the condition was noticed. The affected laminae hung vertically downwards, dead and brown in colour, suspended from the swollen base of the petiole. In slight cases only one or two leaflets were affected, in others the whole leaf died (Fig. 1). Examination of the dead laminae showed a characteristic colour pattern. The original necrotic spot was silvery in colour with a dark centre point. Towards the margin of the spot were concentric lines of dark colour.

The leaves most affected were those about the middle of the plant, neighbouring the fourth and fifth trusses (Fig. 2). From here the condition tended to spread upwards in the plant. Associated with this was a failure of the fourth and fifth trusses to set fruit. Frequently all the fruits failed, or sometimes one or two on a truss developed. The tips of the sepals also withered and died in characteristic fashion. The dead leaves rapidly became spotted with the brownish black fungus *Cladosporium herbarum*, a common secondary invader of the dead and dying foliage of the tomato and other species.

EXPERIMENTAL

Manganese extracted from the soil with molar ammonium phosphate as described by Hoff and Mederske (6) was estimated colorimetrically by oxidation to permanganate with sodium bismuthate according to the method of Peech and English (7). The manganese in the plant tissue was determined by oxidation to permanganate with sodium bismuthate after wet ashing with nitric, perchloric and sulphuric acids.

Soil conditions in the glasshouse

The glasshouse was built over a medium loam soil with weak medium crumb structure, moderate organic matter content and moderately good drainage, being derived from a mixed Cambrian-Ordovician quartzite drift. Initially the soil had a pH of 6.0, a medium level of available calcium, and low levels of available phosphate and potassium. Soil samples taken at the beginning and end of the 1958 season showed that the pH had decreased to 5.0, but good crops were still obtained. In November 1959, after symptoms of manganese toxicity had occurred, soil samples showed that the acidity of the soil had increased sharply, giving a pH of 4.3

There was an evident correlation between the onset of the disease and the phosphate nutrition of the plant. Different sections of the glasshouse had received different levels of application of superphosphate, repeated each spring before planting. The applications given were control (no added phosphate), medium superphosphate (8 per cent P) at $2\frac{1}{2}$ oz. per sq. yard, and high superphosphate at 6 oz. per sq. yard. Otherwise manurial treatment was uniform throughout the house.

The onset of the symptoms was observed first in the plants growing in the control section of the house. With the progress of the season symptoms soon appeared in the medium phosphate plants, but were not seen for some weeks later in the high phosphate plants. As an indication of this, counts taken on 1st and 28th September showed the following percentages of visibly affected plants in each section:

	1*st Sept.*	28*th Sept.*
Control plants	71 per cent	87 per cent
Medium phosphate plants	85 per cent	91 per cent
High phosphate plants	21 per cent	48 per cent

Additional evidence of a relationship between the phosphate nutrition of these plants and the manganese toxicity was evident from the determination of the extractable manganese in the soil from different sections of the glasshouse. Samples taken to a depth of seven inches from the different phosphate treatments gave levels of manganese of the order of 116 ppm. where no phosphate had been applied, falling to 89 ppm. in the medium phosphate section and to 75 ppm. where the heavy dressing has been given.

Manganese Content of the Plant Tissue

On the 20th of July six middle leaves of five plants from each phosphate treatment were analysed for manganese. The lamina and petiole were included in the sampling. The results are given in Table I.

TABLE I

Manganese content of tomato foliage on dry matter basis
(Averages of five samples)

Treatment	Manganese content [1]
Control	4484
Medium phosphate	3556
High phosphate	2260
Sig. diff. ($P=0.05$)	1230
($P=0.01$)	1789

[1] = in parts per million.

Though the difference in manganese level between the medium and no phosphate plants could not be established as significant, the difference between the medium and high phosphate plants was significant at the $P=0.05$ level and that between the no phosphate and the high phosphate plants was significant at the $P=0.01$ level.

Tomato plants were grown in pots of soil from the affected glasshouse, to the stage of the opening of the first flowers. Where the soil had not been limed the manganese content of the tissue (whole plant) was of the order of 3000 ppm. as against 640 ppm. where the soil had been limed to approximately pH 7.0.

DISCUSSION

As an indication of the very high level of manganese in these tomato leaves, leaf samples taken from Ware Cross in a glasshouse at Glasnevin, Co. Dublin, gave a figure of 140 ppm. (average of six samples). Wallace (4) quotes 46 ppm. as being the level of manganese found in healthy tomato tissue (by Nicholas). Comparison may also be made with the manganese content of the leaves of French beans in the Netherlands, where Lohnis (3) found 100-500 ppm. in healthy foliage as against 1000-3000 ppm. in leaves of plants affected by manganese toxicity. On the farm at Johnstown Castle manganese toxicity occurred also in swedes, and Walsh, Golden and Fleming (5) found that superphosphate caused a very considerable reduction in the manganese content of this crop.

Though the occurrence of manganese toxicity would not be expected on a wide scale in this country, the case here described shows that manganese toxicity can occur in newly erected houses on acid soils. Even where the soil reaction was around pH 6.0 as in this case, the soil could soon become acid enough to favour the release of toxic levels of manganese. A factor in causing the increase in acidity in this house was perhaps the use of peat moss in the base dressing, though under the usual conditions of high alkalinity and nutrient levels found in the glasshouse soils peat moss can exert very beneficial effects. Depletion of calcium may also have occurred under the heavy watering usually given to tomatoes, including the large amount given at the winter flooding.

It is possible that cases of manganese toxicity occur without being diagnosed, for under more humid conditions than prevailed during the fine summer of 1959 infection of the drying foliage by *Botrytis cinerea* Fr. would commonly occur, and the condition might be attributed to this fungus.

ACKNOWLEDGEMENTS

Thanks are due to Dr. T. Walsh, who first suggested that the symptoms were attributable to manganese toxicity, to Professor E. Clarke for supplying plant samples from the glasshouse at University College Experimental Farm, Glasnevin, to Mr. J. Brogan and the staff of the Soil Laboratory, Johnstown Castle Agricultural College, for the plant and soil analyses, and to Professor R. McKay, University College, Dublin, for the identification of the fungus.

REFERENCES

1. Lawrence, W. J. C., "*Soil Sterilisation*," London, 1956.
2. Lamb, J. G. D., *J. Dept. Agric., Eire*, **50**: 129, 1953-4.
3. Lohnis, Marie P., *Plant and Soil*, **3 (3)**, July 1951.
4. Wallace, T., "*Diagnosis of Mineral Deficiencies in Plants by Visual Symptoms*," London, 1943.
5. Walsh, T., Golden, J. D. and Fleming, G. A., *Trans. Fourth Int. Congr. Soil Sci.*, 1950, Vol. III.
6. Hoff, D. J. and Mederske, H. J., *Proc. Soil Sci. Soc. America*, **22**: 129, 1958.
7. Peech, M. and English, J., *Soil Sci.*, **57**: 167, 1944.

THE ESTABLISHMENT OF GRASS-CLOVER SWARDS ON BOGLAND BY SURFACE SEEDING

D. P. Collins

An Foras Taluntais, Peatland Experimental Station, Glenamoy, Co. Mayo. Now attached to An Foras Taluntais, Experimental Centre, Ballinamore, Co. Leitrim.

ABSTRACT

A study has been made of some requirements in the establishment of productive grassland on a peat soil by surface seeding. The results of two experiments conducted over a five and four year period respectively are presented. The first experiment showed that calcium and phosphorus were essential to establish a grass-clover sward. The application of nitrogen increased the grass component but reduced the clover content of the pastures. Potassium improved the botanical composition particularly in respect to clover establishment and resulted in increased yield of herbage. A heavy seed rate was unnecessary.

The second experiment indicated that the lime requirement could be reduced to 15 cwt. per acre, that superphosphate was the best form in which to apply a phosphatic fertilizer and that molybdenum gave an increased percentage establishment of clover. The uptake of molybdenum with lime and phosphatic fertilizers are given, and the interaction of lime and ground mineral phosphate is discussed. In the light of the results obtained the economic possibilities of surface seeding are discussed.

INTRODUCTION

There are in Ireland over three million acres of bogland and one and a half million acres of unproductive mountain (1), i.e. approximately twenty per cent of the land surface of the country. The biggest percentage of bogland is found along the west coast, but large tracts also occur in the Central Plain (2). Pockets of peat soil are to be found in most counties, where water-logged conditions resulted from the disruption of the natural drainage by the ice sheet during glaciation.

Very little use has been made of bogland except for the production of domestic fuel. The mountain regions are grazed with sheep but the outputs per acre have been extremely low. The reasons why these areas are not farmed are, altitude, lack of drainage, and low levels of plant nutrients in the soil. The improvement of these areas has always been considered a major project. State grants are obtainable for this purpose but the number of people taking advantage of such schemes is disappointing. Farmers often consider the cost of reclamation prohibitive in making this land productive.

Improvement can be achieved by replacing the existing vegetation with more productive species by establishing sown swards. In mineral soils the most rapid method of introducing new species and improving a pasture is by ploughing and sowing down to grass directly or following a crop rotation. With bogland and mountain areas, however, it is often impossible to bring in suitable machinery to perform this task. Many farmers have attempted improvement of small areas of bogland or

mountain by applying lime or basic slag but the response has been very slow. The method of "surface seeding" whereby lime, fertilizers and seeds are applied over the old vegetation has given a marked improvement and requires the minimum of equipment.

In 1956 experimental work on surface seeding was begun at Glenamoy and an attempt has been made to ascertain the conditions which limit pasture establishment and growth. This paper reports two experiments carried out to establish and maintain productive pasture on bogland using this technique.

EXPERIMENTAL

Peat Characteristics: The blanket peat (3) at Glenamoy varies from 4 to 25 feet deep with an average depth of 13 feet. It is representative of a large area of bogland in western Ireland and of 325,000 acres in its immediate vicinity in North Mayo (1). Analyses of the peat profile showed that the quantities of plant nutrients in the peat were extremely low, and in most cases insufficient to meet the nutritional needs of grass or clover (4). Although there was 1.4 to 1.8 per cent nitrogen in the top layer of peat (4) the amount available for plant growth was small. Most of this nitrogen remains unavailable until decomposition commences.

The indigenous vegetation of the blanket bogs shows no great difference although variations in the prevalence of species depends on soil conditions and situation. *Schoenus nigricans* (black bog rush) is the dominant species of western Ireland blanket peats. *Molinia caerulea* (purple moor grass) is co-dominant and is the only grass species on the bog, occurring in wetter conditions. *Calluna vulgaris* (common heather) is sparse but becomes more prevalent as the peat dries out. Other species occurring are *Erica cinerea*, *Erica tetralix*, *Trichophorum caespitosum*, *Eriophorum vaginatum*, *Rhynchospora alba* and *Myrica gale*. Coverage of the ground by native species is sparse, being only 50 per cent in spring (5), which is advantageous for surface seeding. The seeds have a much better chance of coming in contact with the soil than if there were a dense stand of native herbage.

The initial trial was factorial using the split-plot method. It consisted of 288 plots of 1 sq. perch (28.85 sq. metres) incorporating three levels of nitrogen and phosphorus and two of potassium in the presence and absence of lime. The treatments were 0, 1½ and 3 cwt. per acre calcium ammonium nitrate (20.5 per cent N); 0, 4 and 8 cwt. per acre of basic slag (9 per cent citric acid soluble P); 0 and 2 cwt. per acre of muriate of potash (50 per cent K). Two Cockle Park seed mixtures containing the same quantities of inoculated clover seed, but one with only half the quantity of grass seed were compared. Liming was at the rate of three tons per acre. All treatments were randomised and replicated four times.

The site of the experiments was drained in 1954 at intervals of 50 feet by a Cuthbertson B type plough making drains 3 feet deep, 2½ feet wide at the top and 10 inches wide at the bottom. The experimental plots were more than 4 feet from the drain edge. Since drainage is only effective for such a distance from the drain, it can be assumed that drainage had little effect on the trial (6).

The experiment was designed for observation, but to obtain more precise information about the treatments a cut of herbage was taken from the plots, in 1959, and 1960. These cuts were weighed and dry matter contents determined. In 1960 a botanical analysis was done on representative samples of herbage from the plots. The percentages of sown species in the swards were estimated by the hand separation method (7)

RESULTS

First Series of Experiments

A first class sward was established on the limed area of the experiment by autumn 1957 and by autumn 1958 in the unlimed area. Liming increased the pH from 4.7 to 5.8 in the 0-1″ level. Clover established better than the grasses and its vigour and quality was most spectacular, particularly on the unlimed basic slag plots. *Schoenus nigricans* showed striking growth and vigour on the limed "no phosphate" plots (8). This plant is mainly characteristic of swampy and basic conditions (9). Phosphorus proved to be the limiting factor in establishment of surface seeded pastures. There was good establishment without lime but the sward required a much longer period to develop. Nitrogen application increased the grass component of the sward. This agreed with the results obtained in New Zealand where nitrogen top-dressing trials on peat soil gave spectacular increases in the growth of grass (10). Potassium had a beneficial effect on clover and gave an increase in yield.

Herbage Production: Fertilizers increased output very markedly (Table I). The increased growth of *Schoenus nigricans* on limed, unfertilized plots made it difficult to compare swards on a dry matter basis only. This was because of the higher fibre content of this species compared with sown species. Liming alone failed to produce a grass-clover sward. Established swards were in production earlier and had a longer production season than the swards of native vegetation of the unfertilized plots.

TABLE I

Effect of fertilizer treatments on mean dry matter yields of herbage

Fertilizer treatments (cwt. per acre)	1959 Unlimed	1959 Limed	1960 Unlimed	1960 Limed
No phosphate	182*	775	316	736
4 cwt. basic slag	1414	1642	2700	2429
8 cwt. basic slag	2176	1682	3323	2356
Standard error (P=0.01)	179.2	235.2	212.8	235.2
No nitrogen	952	1062	1777	1539
1.5 cwt. calcium ammonium nitrate	1319	1287	2102	1791
3 cwt. calcium ammonium nitrate	1500	1702	2468	2219
Standard error (P=0.01)	179.2	235.2	212.8	235.9
No potash	1024	1207	1561	1857
2 cwt. muriate of potash	1490	1492	2709	2109
Standard error (P=0.01)	201.6	191.4	123.2	135.5

* = All yields expressed as lb. per acre.

Phosphate application was essential for establishment of sown species and for production from swards. A tenfold increase in yield was obtained with 8 cwt. of basic slag (Table I). Higher yields were obtained by applying basic slag without lime than with lime and response was best with the heavier slag application. Since basic slag contains calcium as well as phosphorus it supplied two of the essential nutrients for plant growth. On unlimed plots, basic slag at 8 cwt. per acre gave significantly better results than at 4 cwt. per acre. On the limed part there was no significant difference between the two treatments. It follows, that there was no advantage in applying the heavier basic slag dressing if lime was also applied.

Nitrogen application increased the yields on all plots. The 3 cwt. per acre treatment of calcium ammonium nitrate was significantly better than the 1½ cwt. treatment (Table I). The responses obtained with nitrogen were similar on both the unlimed and limed parts.

Potassium also gave a significant improvement in the yields of the unlimed and limed areas (Table I), the response being greatest in the unlimed part. It would appear that the higher calcium levels in the limed areas were antagonistic to the uptake of potassium by plants.

Botanical Analysis. Establishment of sown species was better on the unlimed plots than on the limed areas (Table II). This difference in botanical composition was due to a higher clover content in the unlimed swards. There was no establishment of sown species in the "no phosphate" plots. A good strike of clover was obtained in the unlimed basic slag plots but in the limed plots the clover percentage was reduced (e.g. 13.2 per cent and 3.1 per cent respectively). Generally, percentage of clover was higher in unlimed and grass was higher in limed areas. A more balanced grass-clover sward was obtained where basic slag was applied in the absence of lime. Applying 3 tons of lime to the surface of the blanket bog resulted in overliming which reduced the efficiency of phosphate and potash thus limiting growth, particularly that of clover. The higher yields of the unlimed areas (Table I) can be attributed to the greater clover content in the swards.

TABLE II

Percentage of clover and sown grasses in swards with different fertilizer treatments (1960)

Fertilizer Treatments (cwt per acre)	Unlimed			Limed		
	Clover	Grass	Total	Clover	Grass	Total
No phosphate	0.0*	0.0	0.0	0.0	0.0	0.0
4 cwt. basic slag	12.6	68.5	81.1	6.1	65.2	71.3
8 cwt. basic slag	13.2	76.9	90.1	3.1	85.8	88.9
No nitrogen	20.1	58.9	79.0	6.2	61.7	67.9
1½ cwt. calcium ammonium nitrate	12.2	74.7	86.9	4.7	75.6	80.3
3 cwt. calcium ammonium nitrate	7.1	81.6	88.7	3.3	83.6	86.9
No potash	6.4	67.3	73.7	2.3	69.7	72.0
2 cwt. muriate of potash	12.2	82.5	94.7	8.7	78.1	86.8

* = All figures expressed as percentages.

The application of artificial nitrogen reduced the clover content and increased the percentage grass irrespective of lime dressing. The reduction in the percentage clover was greatest in the unlimed part. The effect of applied nitrogen on the botanical composition was similar to its effect in mineral soils (11).

Potash increased the percentages of grass and clover in the plots irrespective of liming. The increase in the clover content was more significant in the unlimed plots. There was no significant difference between the seeds mixtures in either yields or botanical composition of the swards.

Second Series of Experiments

In order to obtain further information regarding the minimum quantities of lime and the most suitable phosphatic fertilizer required to give good results, a second experiment was laid down in May 1957, on a site similar to the previous experiment. Molybdenum was also included in the experiment to investigate its effect on herbage.

The three phosphatic fertilizers compared were, ground mineral phosphate (12 per cent citrate insoluble P), superphosphate (8 per cent water soluble P) and basic slag (9 per cent citric acid soluble P) each applied at 3 cwt. per acre. The basal manuring was one cwt. of muriate of potash and one cwt. of calcium ammonium nitrate per acre. There were three levels of lime (90 per cent $CaCO_3$), O, 15 and 30 cwt. per acre and three of molybdenum, O, $\frac{1}{2}$ and 1 ounce of sodium molybdate per acre. Seeding rates were perennial ryegrass (S23) 10 lb. per acre and wild white clover (S100), 3 lb. per acre.

Experimental blocks were divided into four main plots consisting of a control and one plot each of the three different phosphatic fertilizers. Each plot was subdivided to take all combinations of three levels of lime and three of molybdenum and there were four replications. Sub-plots were 1 sq. perch in area.

Dry matter estimations were made in herbage from the plots in 1958, 1959 and 1960. A botanical analysis was also done on samples taken from the plots in 1959 and 1960. Ryegrass and clover were determined by the hand separation method (7). As in the previous experiment clover made the best establishment of the sown species in the first year. In 1958 both grass and clover were the dominant species in the superphosphate plots. A noticeable feature in the ground mineral phosphate plots treated with lime was the reduction in the percentage establishment of ryegrass and clover. There was better establishment in the limed basic slag plots compared to the unlimed. In the control plots sown species failed to establish even on plots treated with lime, nitrogen and potash. This bore out the results of the first experiment that phosphate in some form was essential for the improvement of this land.

The yields obtained with the different lime and fertilizer treatments for three years are given (Table III). Botanical variations resulting from the different fertilizers are shown in Figure I.

Lime applied in 1957 gave a significant increase in yield and establishment of ryegrass and clover in 1958, 1959 and 1960 (Table III, Figure 1). The most important information gained was that 30 cwt. of lime per acre was not significantly better than 15 cwt. This showed that although liming was important, heavy applications of lime were unnecessary for the establishment of good grass-clover pastures on blanket bog. This was contrary to the general opinion that a heavy lime dressing was required to improve bogland.

Superphosphate with lime was the most suitable phosphatic fertilizer to use in surface seeding giving the highest yields of herbage with the best botanical composition (Table III, Figure 1). The high yield recorded with superphosphate on the unlimed plots in 1958 (Table III) was due to the phosphate stimulating the growth of *Molinia caerulea*, an undesirable species. Superphosphate with 15 cwt. of lime per acre gave slightly higher clover production than basic slag or ground mineral phosphate at the same level of liming. There was no difference between the superphosphate and the basic slag at the 30 cwt. level of lime but it was significantly better than ground mineral phosphate at this level. At both levels of liming superphosphate plots were far superior to basic slag or ground mineral phosphate in ryegrass production.

Basic slag without lime gave the greatest yield of clover and was better than superphosphate or ground mineral phosphate. There was a significant increase in yield (Table III) and establishment of sown species (Figure 1) by applying lime

TABLE III

Effect of phosphatic fertilizers on mean dry matter yields of herbage

Fertilizer treatment (cwt. per acre)	1958				1959				1960			
	L_0*	L_1*	L_2*	Mean	L_0	L_1	L_2	Mean	L_0	L_1	L_2	Mean
Control	537[1]	873	907	769	291	601	601	497	392	972	1017	793
3 cwt. ground mineral phosphate	2486	1389	1254	1709	1456	1097	918	1157	2352	2957	2072	2458
3 cwt. superphosphate	2218	2610	2430	2419	1344	2173	2296	1937	1618	3237	3472	2775
3 cwt. basic slag	1635	1803	1882	1773	1019	1500	1568	1362	1893	2598	2699	2396
Means for lime	1719	1919	1868		1370	1790	1794		1564	2441	2315	
Standard error for lime means		(P=0.05) = 106.6 (P=0.01) = 142.4				(P=0.05) = 124.3 (P=0.01) = 164.6				(P=0.05) = 132.4 (P=0.01) = 173.6		
Standard error for phosphate means		(P=0.05) = 116.4 (P=0.01) = 168.0				(P=0.05) = 358.4 (P=0.01) = 515.2				(P=0.05) = 294.8 (P=0.01) = 365.5		

*L_0 = no lime; L_1 = 15 cwt. ground limestone per acre; L_2 = 30 cwt. ground limestone per acre
1 = All yields expressed as lb. per acre.

with the basic slag. This result differed from that obtained in the first experiment where liming reduced the efficiency of slag. The rate of application of basic slag per acre was lower in this experiment than the lowest treatment of basic slag in the first trial. It follows, therefore, that at least 4 cwt. of basic slag must be applied per acre if lime is not to be applied.

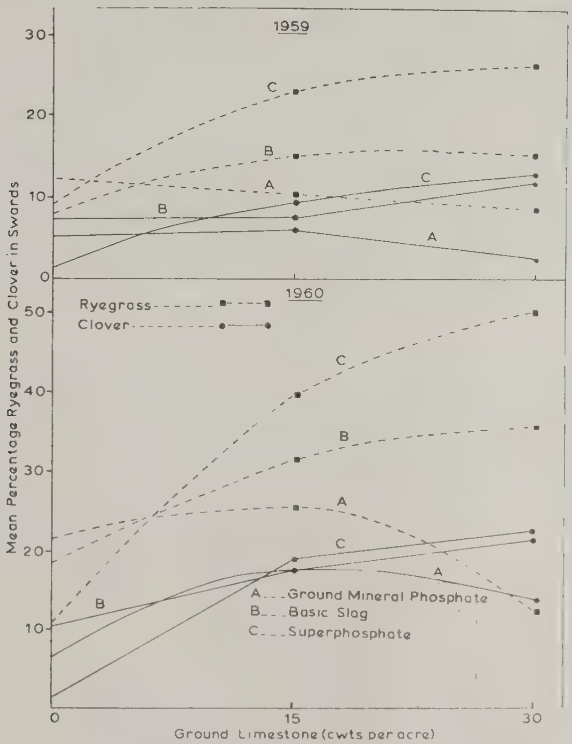


Fig. 1—Variation in ryegrass-clover composition of swards.

Ground mineral phosphate without lime gave the best establishment of grass (Fig. 1) Liming reduced the yields and establishment of sown species and at 30 cwt. per acre there was almost complete failure of sown species. A similar effect has been reported from Germany in experiments where cheap raw phosphatic fertilizer and lime were used on peatland (12). It follows that lime was antagonistic to the uptake of phosphorus as ground mineral phosphate. The change in pH of the top 2 inches of peat (from 4.7 to 5.5) presumably gave conditions which lowered the solubilisation of phosphorus. There was slight weakening in the effect of the 15 cwt. of lime treatment in 1960. On peat, ground mineral phosphate without lime may have some potentialities, but needs further investigation.

Molybdenum In 1958 molybdenum had no effect on the establishment or production of clover or grass. In 1959 increasing the application (from $\frac{1}{2}$ or 1 ounce to $\frac{1}{2}$ or 1 lb. sodium molybdate per acre) gave a significant improvement in clover content. No symptoms of molybdenum deficiency appeared in the untreated plots. In 1960 clover and grass showed a slight response to molybdenum (most apparent in the basic slag plots). Molybdenum uptake by herbage in the various plots was as follows: basic slag 4 ppm, ground mineral phosphate 3.2 ppm., and superphosphate 2.6 ppm. Molybdenum content of herbage grown on peat to which no sodium molybdate had been applied was 0.57 ppm. Liming, by reducing acidity and promoting the availability of molybdenum (13), increased the content in the herbage as follows (in ppm.): unlimed, 0.57; 15 cwt. lime per acre, 1.25; 30 cwt. per acre, 1.59. These results imply that it may be advantageous to use molybdenum to help to establish surface seeded swards on blanket bog which is low in molybdenum (0.4-0.6 ppm. in the top layer) (4). In this experiment the response to molybdenum may have been masked by the effect of nitrogen in the basal manuring (14).

Earthworm Counts Earthworm counts and weight analyses on the second experiment confirmed that superphosphate and lime was the most suitable treatment for the bog. The highest numbers and weights recorded coincided with highest herbage yields and best botanical swards obtained in 1958, 1959 and 1960 (Table IV).

TABLE IV

Effect of phosphatic fertilizers and lime on earthworms in blanket bog (18)

Numbers (in thousands)

Lime treatment	Control	Ground Mineral Phosphate	Superphosphate	Basic Slag
Nil	87	958	174	1,002
30 cwt. ground limestone per acre	35	958	2,091	1,830
		Weight (lb. per acre)		
Nil	81.2	128.4	19.2	146.6
30 cwt. ground limestone per acre	41.2	107.3	520.2	305.6

DISCUSSION

These experiments have shown that the establishment of productive pastures on blanket bog by surface seeding was limited by the availability of calcium and phosphorus. Basic slag, which supplied these two elements, gave a satisfactory sward. Significant responses, in the form of better swards of grasses and clovers were also obtained with nitrogen and potash.

Lime offset the effect of heavy application of basic slag, lowering the yield of clover. However, lime in conjunction with basic slag gave a productive pasture of the sown species one year sooner than basic slag alone. An application of 15 cwt. of lime per acre was sufficient; increasing it to 4 tons per acre reduced the efficiency of applied

phosphate and potash. These results were in agreement with those from New Zealand (10) where peat soils showed a lack of response to liming at more than one ton per acre, and also from the island of Lewis where one half ton of lime per acre gave a conspicuous response (15). The fact that an excellent sward can be established by the application of as little as 15 cwt. of lime and some phosphate per acre has important economic consequences and increases the possibility of using the technique in boglands previously considered unsuitable because of inaccessability.

Superphosphate, in conjunction with lime, gave better results than basic slag, and its use has been advocated in other countries (12, 16, 17). Liming, however, is not recommended with ground mineral phosphate or where basic slag was liberally applied. Nitrogenous fertilizer gave better establishment of grass but reduced the clover content, especially with heavy dressings. Potassium increased total yield and percentage of clover and grass in the sward.

The excellent clover obtained by applying lime, phosphorus and potassium suggests that nitrogen was being symbiotically fixed, thereby overcoming the nitrogen deficiency of peat. At Glenamoy 2 lb. of clover per acre on peat was able to fix 120 lb. of nitrogen symbiotically, equivalent to the application of 6 cwt. of calcium ammonium nitrate (18). Clover can, therefore, reduce the wide carbon-nitrogen ratio (approximately 40 to 1 in peat) and help to overcome the acute nitrogen deficiency of peat (24). It is also cheaper than artificial nitrogen in forming productive pastures.

The results of these experiments are applicable to large tracts in western Ireland. Trials at over twenty centres, using two levels each of superphosphate and basic slag with and without lime, demonstrated the improvements possible with surface seeding on bogland. The technique also makes use of the fact that phosphorus and trace elements are concentrated in the surface layer of the peat (4). The most expensive item in a reclamation programme using this method is phosphatic fertilizer. However, the technique is the cheapest one capable of increasing markedly present carrying capacities of bog and mountain, often the only land available on the west coast of Ireland. The technique has only recently been introduced and will have greatest application in the wetter parts of the country. The high rainfall of these areas (50 inches, or more, annually) "make germination and early growth possible on the damp surface without the necessity of cultivation" (19). Fertilizer application provides better growth conditions for sown species which quickly overcome slower-growing indigenous herbage.

The method has been used in Scotland for nearly twenty years (20) but did not receive much notice until comparatively recently (21, 22). Large areas of the island of Lewis have been improved by this method, and it is also widely used in New Zealand (23). The use of this technique could be the solution to better farming on the bogs and mountains of Ireland.

ACKNOWLEDGEMENTS

Thanks are due to Dr. T. Walsh, Director, An Foras Taluntais, Dublin, for his advice and encouragement; Mr. W. Murphy, Johnstown Castle, Wexford for suggestions; Mr. J. Mulqueen, Peatland Experimental Centre, Lullymore, Co. Kildare for useful discussions, to Mr. P. J. O'Hare, Glenamoy, for helpful criticism, and to Mr. L. Burns and the laboratory staff at the Peatland Experimental Station, Glenamoy, for their co-operation in these investigations.

REFERENCES

1. Reports of the Commissioners appointed to enquire into the nature and extent of the several bogs in Ireland and practicability of draining and cultivating them. 1810-1814 (in R.D.S. Library,Dublin).
2. Barry, T. A., *Internat. Peat Symposium, Section B2*, Dublin. Bord na Mona, July 1954.
3. Tansley, A. G., "*The British Islands and their Vegetation*," Cambridge University Press, Vol. **2**: 714, 1935.
4. Walsh, T. and Barry, T. A., *Proc. Roy. Irish Acad., Section B*, **59** (15): 305, 1958.
5. Boatman, D. J., *ibid., Section B*, **59**: 29, 1958.
6. Armstrong, J. J., Burke, W. and Quinn, E., *J. Dept. Agric., Ireland*, **57**: 149, 1960.
7. Brown, D., "*Methods of surveying and measuring vegetation*,, The Crown Press, Reading, 1954, 79.
8. Murphy, W. E., *Eighth Internat. Grassland Cong., Proc., Reading*, Paper 3A/1: 86, 1960.
9. Tansley, A. G., "*The British Islands and their vegetation*," Cambridge University Press, Vol. **2**: 716, 1935.
10. Thompson, S. B., and Elliot, I. L., *N.Z. J. Sci. Tech., Section A*, **31** (6): 1, 1950.
11. Linehan, P. A. and Lowe, J., *Eighth Internat. Grassland Cong., Proc.*, Reading, Paper 5A/3: 133, 1960.
12. Kraemer, O., *Internat. Peat Symposium, Section F2*, Dublin, Bord na Mona, July 1954.
13. Walsh, T., Neenan, M. and O'Moore, L. B., *J. Dept. Agric., Ireland*, **48**: 32, 1953.
14. Kline, C. H., *Agric. Food Chem.*, **2** (8): 404, 1954.
15. Clouston, D., *Scot. J. Agric.*, **15** (2): 280, 1932.
16. Grant, J. W., Lumsden, C. I. and Gillespie, A., *Scottish Agric.*, **38** (2): 79, 1958.
17. Levey, E. B., *N.Z. J. Agr.*, **44**: 79, 1932.
18. Mulqueen, J., Soil Fertility Department, An Foras Taluntais. Private communication of findings at the Peatland Experimental Station, Glenamoy.
19. Ogg, W. G. and MacLeod, A., *Scot. J. Agric.*, **20** (2): 179, 1937.
20. *Idem, ibid.*, **16** (2): 218, 1933.
21. Gardner, A. L., *Agriculture*, **64** (5): 239, 1957.
22. Gardner, A. L., Hunt, I. V. and Mitchell, I. W., *J. Brit. Grassland Soc.*, **9** (3): 161, 1954.
23. McM. Bull, H., *N.Z. J. Agric.*, **68**: 429, 1956.
24. Kilnoe, J. R., *Soil Geology of Ireland*, Alex. Thom, Dublin, 1907, 157.

DRAINAGE INVESTIGATION ON BOGLAND

The Effect of Drain Spacing on Ground Water Levels

W. Burke

An Foras Taluntais, Soil Physics Department, Kinsaley, Co. Dublin

ABSTRACT

Drains installed in blanket peat have a very localised effect. A lowered ground water level is found only to a distance of 5 or 6 feet from the edge of the drain. Hence with drain spacings of 25, 50 and 100 feet,the areas remaining undrained were respectively 60, 80 and 90 per cent. There was a maximum seasonal fluctuation of 12 inches in the water table, but no permanent drainage effect.

INTRODUCTION

The reclamation of peatland for agriculture has been practised for centuries, and has been attempted in all countries where peat deposits occur. In Ireland there are approximately three million acres of peat. In many districts peatland is the only land available for agriculture (1). Most of the peat reclamation work done has been by farmers using traditional methods. Drainage then was mainly achieved by covered sod drains.

Recently, Bord na Mona (The Irish Peat Board) have developed methods for the large-scale drainage of peat. These methods are satisfactory for industrial purposes, but have not proved adequate for agriculture.

The drainage of blanket peat presents a special problem, since it is usually more gelatinous and less permeable than the Irish midland peats.

Peat Drainage In Other Countries

Information on peat drainage from other countries is often contradictory and there is disagreement on exact drainage requirements. In Russia, Yangal recommended spacing not greater than 40 metres between mole drains for a peat composed chiefly of sedges, moss and reeds (2). German practice recommended drain spacings of 20-30 metres for tillage and 25 to 40 metres for grass in deep low bog. For deep raised bog, spacings of 12-20 metres for tillage, and 15-25 metres for grass were advised. Kramer in Bavaria recommended a spacing of 20-25 metres for low bogs and 8-10 meters for high bogs (4). Venier Bog, in France, had drains 0.75 metres deep spaced at an average of 50 meters.(5) In the Florida Everglades where very large acreage of

peat and muck soils have been reclaimed, drains are spaced at 660-1000 feet with internal mole drains 30 inches deep at 12-15 feet spacings (6). In New Zealand good results have been obtained on peat by spacing mole drains at 10 feet (7). This system gave a ground water level of 10 inches in winter and 24 inches in summer. At Nephin Beg in Ireland, drains 20 inches deep spaced at 10 feet were used for forestry work (8).

Ground Water Levels and Crop Yields

Experiments to correlate the depth to ground water level with crop yields have been done in many countries on mineral soils but information on this aspect of peat land utilisation is limited. Such a study was carried out at the University of Minnesota in the early 1930's (9). For grass, best results were obtained with a $1\frac{1}{2}$-2 feet depth to ground water level. This depth was also found satisfactory for many crops in the Everglades region, while grasses did well at appreciably shallower depths (6). The effect of ground water level on crops on Fen peat has been studied in England by Nicholson and Firth (10). Their results indicated an optimum depth to ground water level of $2\frac{1}{2}$ to 3 feet for most crops with good results from potatoes and celery at a depth of 2 feet.

EXPERIMENTAL

Drainage Investigations at Glenamoy

Glenamoy, in County Mayo, on the west coast of Ireland, has an average annual rainfall of 50 inches (270 rain days) and the peat type there is representative of blanket bog in the western part of the country. Drainage and related problems at Glenamoy have been studied as follows: (a) the collection of data on the physical properties of drained and undrained peat; (b) method of drainage; (c) cultural treatments; (d) effect of drainage and soil structure on plant growth. Records of moisture content, drainage water run-off, bog shrinkage, ground-water levels, and moisture pressures above and below ground-water level were obtained.

Ground Water Level Assessment

Because of the physical characteristics of blanket peat--high water content, extremely low permeability and massive structure—it was necessary to determine whether the ground water level, as found in observation wells, coincided with that within the peat mass. For this test, the true level was taken as the locus of those points at which the water in the peat was at atmospheric pressure. It was assumed that moisture movement in the peat was sufficiently slow to approximate equilibrium conditions. Tensiometers were inserted at various depths and records were kept of tensions and observed ground-water levels over a period of several months. These records showed approximate agreement between the two methods of ground-water level determination. Thus, the well method of observation was regarded as sufficiently accurate for this study.

RESULTS

Effect of Drain Spacing

The effect on ground water level of open drains 3 feet deep spaced at 25, 50 and 100 feet apart was studied. A uniform area with a slight slope was selected. For each spacing three lines of wells at right angles to the drains were installed. Each well was 6 feet deep, 4 inches in diameter and lined with 6 field drainage clay tiles, placed

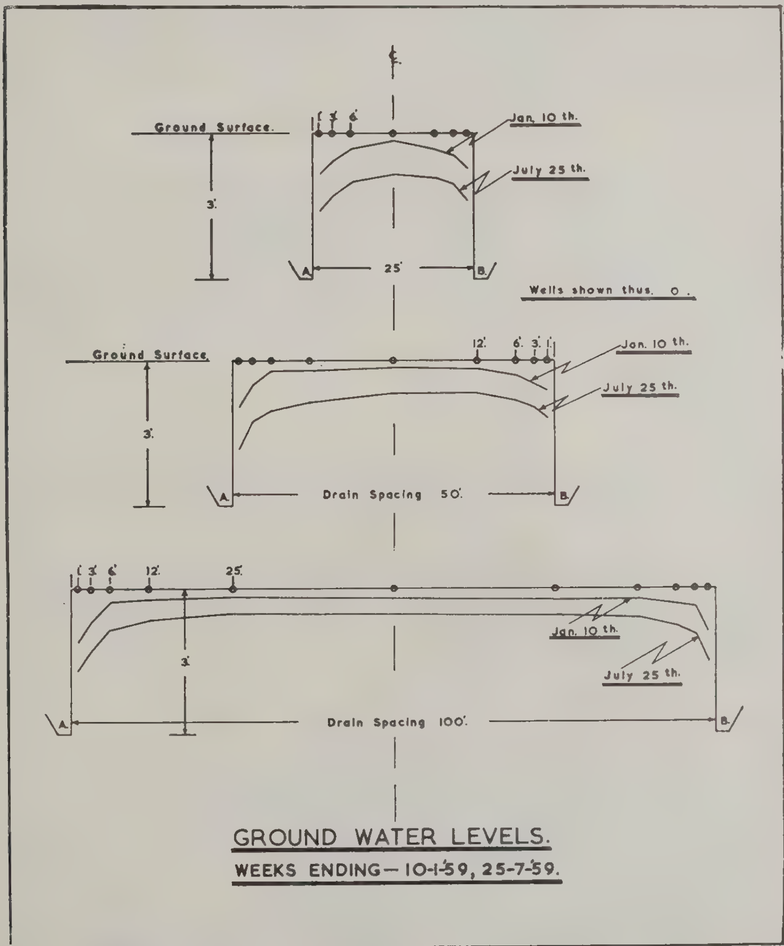


Fig. 1—Effect of drain spacing on average ground water levels for selected winter and summer weeks.

vertically one above the other. Depth to ground water level was measured from the upper end of the top tile which was made to coincide exactly with the surface. Readings were taken daily in all wells except on very wet days. There were a total of 81 observation points from which over 20,000 readings per annum were obtained. The position of observation wells and the water level in relation to drain spacings for winter and summer periods are shown (Fig. I). It will be noted that, irrespective of drain spacing, ground water level commenced to fall at a point approximately 6 feet from the drain edge. Elsewhere it remained parallel to the surface and at the same height as in the undrained condition. Additional data on this point are presented (Table I). Average ground water levels for selected weeks in 1958 and 1959 in wells 6 feet and 12 feet from drain edge (and rainfall for each period) are given.

TABLE I

Average depth to ground water, and rainfall, for typical weeks, winter and summer, 1958-9

Week ending	1 Feb. 1958		19 July 1958		10 Jan. 1959		25 July 1959	
Rainfall (inches)	0.85		0.34		1.14		0.65	
Distance from drain (feet)	6	12	6	12	6	12	6	12
Drains 25 ft. apart	3.7*	1.7	12.7	10.3	3.7	2.0	12.3	10.0
Drains 50 ft. apart	2.3	2.3	11.3	10.3	2.7	2.3	12.0	10.7
Drains 100 ft. apart	2.3	2.3	12.6	9.7	3.6	3.0	10.3	8.0

* = All depths expressed in inches.

A further series of tests is in progress (begun in 1959) with drains spaced at 8, 12, 16 and 20 feet by means of a plough specially developed for peat drainage (12). Early results show that a drain spacing of 10 to 12 feet is necessary for overall lowering of ground water level.

REFERENCES

1. Walsh, T. W., O'Hare, P. J. and Quinn, E., *Advanc. Sci.*, **57**: 405, 1958.
2. Yangal, A. N., *Dokl. Vsesou. Akad. S. Kh. Nauk.*, **12**: 26, 1940.
3. "*Drainage of Bog Soil*," German Standard (DIN 1185), Berlin, 1950.
4. Kraemer, O., *Internat. Peat Symp., Sect. F2*, Dublin, Bord na Mona, 1954.
5. Ferroniere, Y., *ibid., Sect. F2*, 1954.
6. Clayton, B. S., Neller, J. R. and Allison, R. V., "*Water Control in the Peat and Muck Soils of the Florida Everglades*," Bull. 378, Univ. Florida Agric. Expts. St., 1942.
7. Van der Elst, Hupkens, F. E. C. Information Ser. No. 12, N.Z. Dept. Sci. Ind. Res., 1956.
8. McEvoy, T. F., *Internat. Peat Symp., Sect. F2*, Dublin, 1954.
9. "*A Study of Ground Water Levels on Yields of Crops Grown on Peatland*," Bull. 330, Univ. Minn. Agric. Expts. St.
10. Nicholson, H. H. and Firth, D. H., *J. Agric. Sci.*, **50**: 243, 1958.
11. Walsh, T. and Barry, T. A., *Proc. Roy. Irish Acad.*, **59b**: 15, 1958.
12. Armstrong, J. J., Burke, W. and Quinn, E., *J. Dept. Agric. Eire*, **57**: 149, 1960.

THE AVAILABILITY OF COPPER FROM COPPER-HUMIC ACID COMPLEXES

Marie T. Ennis and J. C. Brogan

An Foras Taluntais, Soils Division, Johnstown Castle, Co. Wexford

ABSTRACT

The frequent occurrence of copper deficiency in plants grown on peat soils has led to the theory that such soils fix copper in a form not readily available to plants. Though laboratory studies have demonstrated the formation of water-insoluble compounds between copper and soil organic matter, there seems to have been no assessment of the availability of such copper as a nutrient.

This report describes the preparation of three copper-humic acid complexes wherein the chemical binding of the copper is related to its resistance to acid extraction. The availability of the copper in these complexes as a nutrient for oats is assessed in a pot experiment by comparison with copper sulphate. The results show that the complexes have different availabilities and that the most strongly bound copper is virtually unavailable.

INTRODUCTION

There are approximately three million acres of peatland in Ireland and in general these areas are very low in fertility. One of the most striking deficiencies observed is that of copper, particularly in cereals (1). The symptoms of copper deficiency and reclamation disease, which are synonymous, have been known for thirty years and have mostly been associated with bogs or highly organic soils. This led to the conclusion that soil organic matter caused fixation of copper but little quantitative work had been done on the nature, amounts and stabilities of the compound or compounds formed. Hoffman (2) was the first to show that addition of humic acid to sand in which cereals were grown caused reduction in yields and symptoms of reclamation disease. Brun (3), Steenbjerg (4) and Vermaat (5) have advanced evidence from field experiments in support of these findings. The literature however is conflicting and Lundblad (6) found no evidence of copper fixation by soil organic matter. Schlichting (7) showed that *Aspergillus niger* could utilise almost all the copper bound by humus. Recently Scharrer (8) in experiments with spring cereals on copper-deficient soils showed that although there was a decrease in availability of copper with increasing organic matter, there was no direct evidence of copper fixation.

Laboratory studies on the nature of the chemical binding between copper and soil organic matter have been carried out by several workers. Hasler (9) showed that copper is held very tenaciously by organic matter. Lucas (10) and Beckwith (11) titrated

copper-saturated soil organic matter preparations with sodium hydroxide and hydrochloric acid and related the rate of release of copper to the strength of binding, and Beckwith (11) predicted that copper need not necessarily be unavailable to plants from the complexes formed. Using a copper amalgam electrode, Dawson (12) demonstrated that a number of complexes of different stabilities are formed between copper and peat, and concluded that the most strongly bound copper is attached to the lignin- and protein-derived fractions. Broadbent (13) fractionated the copper complexes of a soil organic matter preparation by saturating it with copper acetate and then leaching exhaustively with increasing strengths of hydrochloric acid (0.01, 0.05, 0.1 and 1.0 normal).

None of these laboratory investigations had been related to studies of availability of copper to plants so whereas there was evidence that copper could react with soil organic matter in several ways, its availability from any of these forms was unknown. It was decided to prepare a number of peat-copper complexes of different stabilities by a method based on Broadbent's (13) fractionation and to compare the plant uptake of copper from these with that of copper sulphate.

EXPERIMENTAL

Preliminary experiments had shown that the copper absorption capacity of peat was principally due to the humic acid fraction. To avoid using large quantities of peat in a pot experiment, it was decided to prepare copper complexes from humic acid rather than from raw peat. It was also hoped that this approach would help to eliminate interfering factors, e.g., water holding capacity which would be considerable if peat were used in each pot.

Preparation of humic acid

Large quantities of wet peat from the top 9 inches of a blanket peat at Glenamoy, Co. Mayo (14) were treated with 2 per cent NaOH at 60°C. for 8 hours and allowed stand over night. The mixture was centrifuged and the extract filtered and acidified to pH 2 with hydrochloric acid. The precipitated humic acid was separated by centrifuging, dried in a vacuum desiccator, ground in a mortar and washed thoroughly with water to remove excess acid. About 400 g. of humic acid were prepared in this manner of which half was kept as a control sample. The copper contamination was determined after wet ashing.

To ensure that the copper complexing properties of the humic acid had not been altered by the extraction, separate samples of peat and humic acid were compared by a modification of Broadbent's (13) technique. A one gram lot of each was placed in a 1 cm. chromatographic column and saturated with copper sulphate. The columns were then eluted with 0.01 normal hydrochloric acid and successive 2 ml. fractions of the effluent collected on an automatic fraction collector and analysed for copper concentration. When the copper concentration in the effluent reached a minimum,

the acid concentration was increased to 0.1 normal and the procedure repeated. The columns were subsequently eluted with 1.0 normal acid in the same way. The elution curves for peat and humic acid with the three acid strengths are shown in Fig. I.

Peat contained 30 per cent by weight of humic acid and it had been established that the copper-holding capacity of peat was largely due to the humic acid fraction. It was therefore expected that the amount of copper bound by one gram of humic acid would be approximately three times that bound by one gram of peat. It can be seen in Fig. I that this proved to be as expected. It is also evident that the curves are very similar in shape and so it was assumed that release of the metal from a copper humic acid complex would be similar to its release from peat. All analyses for copper were carried out by the method of Andrus (15) using zinc dibenzyldithiocarbamate.

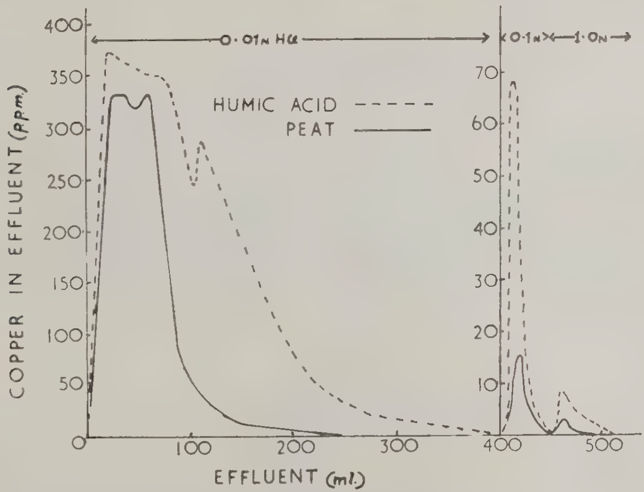


Fig. 1—Elution patterns of peat and humic acid with increasing strengths of HC1. (Note that a five-fold increase of the ordinate scale was necessary to represent the 0.1 and 1.0 normal HC1 peaks).

Preparation of copper-humic acid complexes

Chromatographic columns of one inch diameter were packed with 10, 30 and 100 g. (columns I, II and III) respectively and were completely saturated with copper sulphate. They were leached with glass distilled water and subsequently leached with 0.01 normal HCl until the copper content of the effluent was negligible. The contents of column I were freed from acid with glass distilled water, dried in vacuo and a portion analysed for copper content. Columns II and III were leached with 0.1 normal HCl until the effluent was free from copper and the contents of column II washed with water, dried in vacuo and analysed. Column III was further leached with 1.0

normal HCl until the effluent was free from copper and the contents dried and analysed. Table I shows the results of the copper analyses for the three humates.

TABLE I

Copper content of humic acid and copper humate preparations[1]

Untreated humic acid	Copper humate		
	Column I[2]	Column II[3]	Column III[4]
30 (contamination)	2850	1260	226

1 = Results expressed as parts per million
2 = Leached with 0.01 normal HCl
3 = Leached with 0.01 and 0.1 normal HCl
4 = Leached with 0.01, 0.1 and 1.0 normal HCl

Pot experiment

Fine Belgian silica sand was washed with hot 6 normal hydrochloric acid, neutralised with sodium carbonate and washed thoroughly with glass distilled water. After treatment the sand still contained 1-2 *u*g. copper per 100 g. Pyrex pots (1 gallon capacity, 7 inches diameter) were used in the experiment. They were washed with hot 6 normal hydrochloric acid and rinsed thoroughly with glass distilled water. The design of the experiment is shown in Table II. There were three replications of each treatment and the experiment was completely randomised.

TABLE II

Design of the experiment

Treatment	Humic acid or humate added to sand culture	Copper added to nutrient solution[1], (*u*g./l)
a	—	—
b	—	15
c	—	40
d	—	64
e	0.53 g. column I humate (1500 *u*g. Cu)	—
f	2.25 g. column I humate (6400 *u*g. Cu)	—
g	1.19 g. column II humate (1500 *u*g. Cu)	—
h	5.08 g. column II humate (6400 *u*g. Cu)	—
j	6.64 g. column III humate (1500 *u*g. Cu)	—
k	28.32 g. column III humate (6400 *u*g. Cu)	—
l	2.24 g. humic acid	64
m	5.08 g. humic acid	64
n	28.32 g. humic acid	64
o	2.5 g. humic acid	—

1 = Nutrient solution prepared according to Hewitt (16), no copper added.

The appropriate quantities of humic acid and copper humates were mixed thoroughly with approximately 250 g. of sand in a mortar and then uniformly mixed with 6 kilogrammes of sand in an end runner mill with a rubber mortar before potting. Each filled pot was leached with two litres of nutrient solution and sown with twenty oat seeds (Sun II variety) which were thinned to ten plants per pot after two weeks.

The appropriate nutrient solutions were applied as often as required. Because of slower drainage than expected and an excessively wet summer only 18 litres of nutrient solution were required during the growing season. Thus treatments (*b*), (*c*) and (*d*) received only 270, 720 and 1152 *ug*. of copper respectively whereas it was intended that they should receive 1500, 4000 and 6400 *ug*. of copper respectively over the growth period to make them comparable to the other treatments.

RESULTS

In cases of severe copper deficiency young oat plants develop "white tip." This is characterised by the edges of the leaves becoming light green to pale yellow and the tips becoming white to colourless. In less severe cases of copper deficiency, the stunted plants may flower but only blind ears are formed. In the above pot experiment, no visual symptoms of "white tip" developed during growth but a number of pots showed stunted plants with blind ears. Pots were harvested before the plants were fully ripe and yields of grain plus chaff and of straw were noted. The average yields and copper contents from the three replications in each treatment are shown in Table III.

TABLE III

Average yields of dry matter and copper and nitrogen contents

Treatment	Grain plus chaff			Straw		
	Dry matter[1]	Cu[2]	N[3]	Dry matter	Cu	N
a	4.4	0.7	2.1	44.0	1.7	2.5
b	27.4	1.5	2.3	48.1	2.8	1.3
c	25.0	2.4	2.4	44.6	3.9	1.5
d	28.2	3.3	2.3	46.0	4.2	1.3
e	26.1	1.3	2.4	48.0	3.4	1.6
f	25.0	2.6	2.6	48.0	4.3	1.5
g	22.5	0.8	2.4	51.8	2.8	1.6
h	27.6	1.4	2.4	44.7	2.2	1.1
j	6.1	0.4	2.4	42.9	0.4	2.6
k	16.0	0.3	2.9	50.4	0.4	1.7
l	27.3	2.8	2.3	48.8	4.2	1.5
m	29.6	3.1	2.3	50.0	3.7	1.3
n	25.0	3.2	2.3	45.2	3.3	1.4
o	2.7	0.3	2.2	34.4	0.1	3.6

1 = Weight in g. oven dried material (100°C).
2 = parts per million of dry matter.
3 = per cent of dry matter (Kjeldahl).

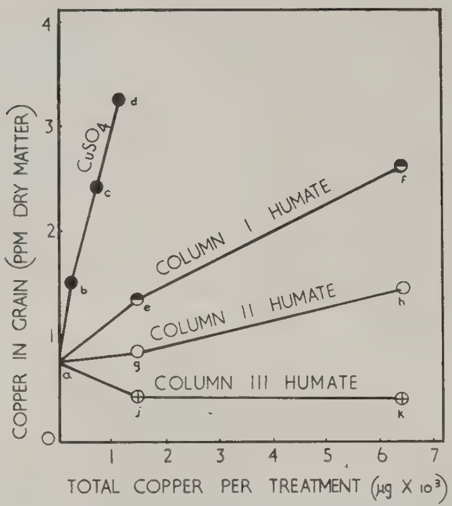


Fig. 2—Availability of copper from the three copper-humic acid preparations as indicated by the copper content of the grain in earh treatment.

DISCUSSION

The results of the experiment show that there are marked differences in the availabilities of copper from the different sources. This is illustrated in Fig. 2 where the slope of each line is a function of the availability of the copper from each source. It can be seen that the availability of the copper from the three humates varied according to the method of preparation. The copper in all three humates however was considerably less available than from the copper sulphate.

There were no significant differences in straw yields but grain yields of treatments (*a*), (*j*), (*k*) and (*b*) were much lower than in the other pots. The reduced yields in (*j*) and (*k*) coupled with the significantly low copper of grain and straw show clearly that copper cannot be released from column III humate quickly enough to support normal plant growth. The lowest yields of all were obtained from treatment (*o*) which also showed the lowest copper content, and it is obvious that the humic acid added has competed with the plant for the small amounts of copper which were present in the control pots (*a*) as contamination. None of the plants showed symptoms of any disease other than copper deficiency and treatments (*l*), (*m*) and (*n*) showed that in the presence of excess copper, high levels of humic acid had no detrimental effect on plant growth. The copper content of grain and straw from treatment (*n*), however, was lower than those from treatments (*l*) and (*m*). This is undoubtedly due to the absorption of some of the added copper from solution by the large amount of humic

acid present. These effects are very evident in Fig. 3 which shows the average total copper uptake per pot for each treatment.

The oats were analysed for nitrogen, phosphorus, potassium, calcium and magnesium to determine the variation in their uptake with the different copper treatments. Only nitrogen showed significant variation with treatment and the figures are included in Table III. Wood (17) and Lucas (18) have shown that the nitrogen content of both grain and straw generally increase with copper deficiency. In the above experiment, however, the nitrogen level in the grain seemed independent of treatment while that of the straw increased with decreasing copper levels.

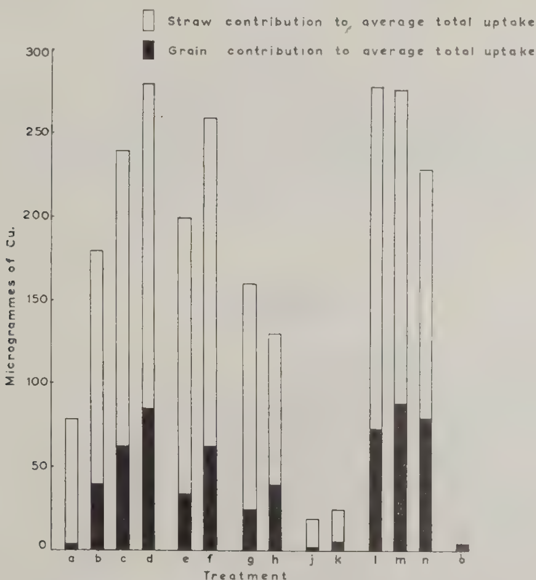


Fig. 3—Average total copper uptake per pot for each treatment. (Obtained by multiplying average yields of grain and straw by their copper contents).

The results presented show that copper forms a number of complexes with humic acid and that its availability to plants varies with the complex formed. They also show that Broadbent's technique (13) of leaching with different strengths of hydrochloric acid is a useful index of this availability. It should be noted that the choice of acid strengths used (0.01, 0.1 and 1.0 normal) was completely arbitrary and that the fractions eluted did not correspond to specific chemical bonding.

The chemical nature of the compounds formed remains obscure. From methylation studies of soil organic matter preparations Broadbent (19) deduced that a large

part of the copper-binding capacity could be accounted for by the carboxylic groups present. Work carried out at this laboratory is in agreement with this view. Broadbent (13) also suggested that this carboxylate copper was rather weakly bound and corresponded approximately to that eluted by 0.01 normal hydrochloric acid (Fig. 1). Copper in this form was not used in the plant growth experiment since very few organic soils have levels of copper high enough to contain this type of compound. The more stable compounds are likely to be chelates, but little satisfactory evidence has been offered on their chemical nature. Work is proceeding on the elucidation of the structure of these chelates as it is believed that such data will help enlighten the general study of the influence of soil organic matter on nutrient supply to plants.

ACKNOWLEDGEMENTS

The authors thank Dr. T. Walsh for his advice, Mr. L. Doyle who carried out much of the experimental work and Mr. M. O'Keeffe for statistical analyses of the results. The Soil Survey Department very kindly compiled the graphs.

REFERENCES

1. Mulqueen, J. (personal communication).
2. Hoffman, W., *Bodenk. PflErnahr.*, **13**: 139, 1939.
3. Smith-Brun, T., *Bergens Mus. Aarb.*, **6**: 1, 1945.
4. Steenjberg, F. and Boken, E., *Plant and Soil*, **2**: 195, 1950.
5. Vermaat, J. C. and van der Bie, G. T., *ibid.*, **2**: 257, 1950.
6. Lundblad, K., Stranberg, O. and Ekman, P., *ibid.*, **1**: 277, 1949.
7. Schlichting, E., *Acta Agric. Scand.*, **5**: 313, 1955.
8. Scharrer, K. and Schlaumlaffel, E., *Z. PflErnahr., Dung.*, **89**: 1, 1960.
9. Hasler, A., *Mitt. Lebensm. Hyg., Bern*, **34**: 79, 1943.
10. Lucas, R. E., *Soil Sci.* **66**: 119, 1948.
11. Beckwith, R. S., *Austral. J. Agric. Res.* **6**: 685, 1955.
12. Dawson, J. E. and Nair, C. K. N., *in* "Copper Metabolism" (edited by W. D. McElroy and B. Glass), Baltimore, Johns Hopkins Press, 1950, 315.
13. Broadbent, F. E., *Soil Sci.*, **84**: 127, 1957.
14. Walsh, T. and Barry, T. A., *Proc. Roy. Irish Acad.*, **59** (Sec. B): 305, 1958.
15. Andrus, S., *Analyst*, **80**: 514, 1955.
16. Hewitt, E. J., "Sand and Water Culture Methods used in the study of Plant Nutrition," Commonwealth Agric. Bureau, Tech. Comm. No. 190, 1952.
17. Wood, J. G. and Womersley, H. B. S., *Austral. J. expt. Biol. med. Sci.*, **24**: 79, 1946.
18. Lucas, R. E., *Soil Sci.*, **65**: 461, 1948.
19. Broadbent, F. E. and Bradford, G. R., *ibid.*, **74**: 447, 1952.

SUPPLEMENTARY VITAMIN D_3 FOR LAMBS

S. Curran and J. P. Crowley

An Foras Taluntais, Animal Production Division,
Dunsinea, Castleknock, Co. Dublin

ABSTRACT

In two lowland flocks in which dates of lambing had been recorded vitamin D_3 was administered parenterally within 21 days of birth to one member of each pair of twin lambs and to half of the single lambs. The growth rate of the lambs was determined by weighing at time of treatment and again when the animals were 50-70 days old. There was no significant difference in growth rate between control and treated single lambs. In the case of the twins the overall difference between treated and control animals was not significant, but detailed examination of the data suggests that treatment within the first few days of birth effected an appreciable increase in growth rate over the trial period.

INTRODUCTION

It is generally assumed that animals which are exposed to solar irradiation are adequately supplied with vitamin D. In sheep, however, the close covering of wool may act as a barrier to sunlight and it is reasonable to suggest that under certain conditions sub-optimum elaboration of vitamin D could lead to unthriftiness. The unpublished results of field-scale investigations involving over 500 Blackface ewes have been reported from England (1). In these trials intramuscular injection of the ewes with vitamin D_3 about two months prior to lambing appears to have conferred substantial benefits on the flock in respect of general health, fleece yield and quality, and the growth rate of the lambs. On the other hand the preliminary results from an experiment being conducted at Great House (N.A.A.S. Experimental Husbandry farm) indicate that a single intramuscular injection of vitamin D_2 failed to produce any improvement in liveweight gain and general condition in gimmer hoggs (2).

Neseni, Altenkirch and Otto (3) in Germany, working with Merino wethers which were being fed a mildly rachitogenic diet, showed that supplementary vitamin D_2, administered orally or parenterally, improved both liveweight gain and feed efficiency over a period of 80 days. The difference between treated and control animals was, however, not statistically significant. In Ireland, Crowley (4) has recorded an outbreak of clinical rickets in November-born lambs in a lowland flock.

The data presented in this paper relate to a trial which was undertaken to test the effect of parenteral administration of vitamin D_3 on the growth rate of spring-born lambs.

EXPERIMENTAL

The trial was conducted on two farms, one in Co. Meath (A), the other in Co. Dublin (B). In both these counties fat lamb production is a common enterprise. Both flocks consisted of ewes of the Galway breed which had been mated to Suffolk rams the previous autumn. All the ewes had received routine supplementary concentrate feeding prior to lambing and for a period of about two weeks after lambing, until both ewes and lambs were transferred from the lambing paddocks to fresh pasture.

On farm A two lots of lambs (Lots 1 and 2) were used, while on farm B one lot (Lot 3) was involved in the trial. Lot 1 contained 15 pairs of twins and 21 singles, Lot 2, 14 pairs of twins and 13 singles and Lot 3, 7 pairs of twins and two singles. In each lot, treatment, consisting of a subcutaneous injection of 200,000 International Units of vitamin D_3 in ethyl oleate ("Suntax," Crookes' Laboratories, Ltd.), was applied to half of the available lambs, the other half being used as controls. In the case of twin lambs one member of each pair was treated. Single lambs were not paired. The allocation of treatment to both twins and singles was such as to preserve an approximate balance between males and females but was otherwise random. Lambs in Lot 1 were treated on March 7, Lot 2 on March 28 and Lot 3 on April 8, 1960. Lamb weights were recorded at time of treatment and on two subsequent dates. The data discussed on this paper refer to liveweight gains over a 63-day period following treatment for Lot 1, a 60-day period for Lot 2, and a 49-day period for Lot 3.

RESULTS

The results obtained with both twins and single lambs are shown (Table I).

TABLE I

Mean liveweight gains and standard errors over the trial period

Lot	Trial Period (days)	Twins		Singles	
		Control	Treated	Control	Treated
1	63	44.7±1.4*	44.5±1.2	56.4±2.4	57.9±2.4
2	60	46.6±1.6	49.0±2.0	60.1±2.5	59.8±2.6
3	49	40.9±3.2	42.0±3.3	—	—
Combined	—	44.7±1.1	45.9±1.2	57.8±1.9	58.6±1.8

* All results expressed in lb.

Twin lambs

The response to treatment is represented by the difference in liveweight gain between the treated and the control twin, the response being regarded as positive if the treated twin showed a larger gain in weight than the control. Two factors other than vitamin D treatment which might influence this difference in weight-gain were investigated, namely difference in sex and difference in initial weight between the twins. Corrections for these two factors were estimated by regression analysis within lots. The correction factors involved were: for sex, subtract six lb. from the weight gain of the male lamb, and for initial weight subtract 0.6 times the difference in initial weight from the weight gain of the initially heavier lamb. However, the correction for initial weight was subject to much uncertainty, and it was found that almost equally good results could be obtained by adjusting for sex only, subtracting seven lb. from the weight gain of male lambs. No evidence was found for variation between lots in the correction factors.

Average values of response to treatment in each lot adjusted by both methods (sex and initial weight, and sex only) are shown in Table II, together with the corresponding standard errors. It will be seen that none of the figures for adjusted average response is significantly different from zero.

TABLE II

Response to treatment as indicated by difference in liveweight gain between treated and control twin

	Average response to treatment (lb.), with the standard errors	
	Adjusted for sex and initial weight difference	Adjusted for sex difference only
Lot 1	$+0.5 \pm 1.6$	$+0.3 \pm 1.7$
Lot 2	$+0.7 \pm 1.7$	$+1.0 \pm 1.7$
Lot 3	$+1.8 \pm 2.4$	$+2.0 \pm 2.4$
Combined	$+0.7 \pm 1.0$	$+0.9 \pm 1.1$

Detailed results for twin lambs are shown in Table III, the last column showing response to treatment adjusted for sex difference only. Although some negative correlation appeared between adjusted difference in liveweight gain and initial weight of the pair it was found that when initial weight was adjusted for age on the basis of a growth rate of 0.7 lb. per lamb per day, this correlation was no longer apparent. (This figure, 0.7 lb., was obtained by regression of initial weight on age in the present data.)

TABLE III

Comparison of weight gains in treated and control twin lambs

	Age at treatment (days)	Initial weight of pairs (lb.)	Weight gain (lb.)		Apparent response to treatment (lb.)	
			Treated	Control	As observed	Adjusted to sex
Lot 1	4	34	45F*	45F	0	0
	4	29	35M*	40F	—5	—12
	4	28	42F	45M	—3	4
	4	30	47F	48F	—1	—1
	4	34	46M	45M	1	1
	4	32	36F	58M	—22	—15
	3	34	50M	48M	2	2
	3	37	39F	45M	—6	1
	3	37	41M	35M	6	6
	Birth	27	47F	38F	9	9
	Birth	25	46F	46F	0	0
	Birth	30	47M	42M	5	5
	Birth	27	48F	42F	6	6
	Birth	29	48M	47M	1	1
Lot 2	21	44	37F	45M	—8	—8
	20	47	53M	49M	4	4
	18	50	45F	46F	—1	—1
	18	45	34F	42F	—8	—8
	14	40	38F	38F	0	0
	13	39	51M	49F	2	—5
	13	41	46F	51M	—5	2
	12	43	59M	53M	6	6
	9	36	54M	46M	8	8
	6	29	49M	48M	1	1
	5	25	51F	50F	1	1
	4	27	46F	57M	—11	—4
	3	21	46F	38F	8	8
	2	25	57M	40F	17	10
Lot 3	10	41	51M	41F	10	3
	9	39	41F	45M	—4	3
	8	29	40M	37F	3	—4
	8	28	39F	50M	—11	—4
	7	39	58M	50M	8	8
	7	31	32F	37F	—5	—5
	Birth	23	39F	26F	13	13

*F = Female M = Male

There was, however, some suggestion of a relationship between age at treatment and adjusted difference in liveweight gain. In particular, of the 11 pairs of twins in which treatment was applied between birth and 3 days of age, 10 showed a positive response and one a zero response, the average response to treatment (as measured by adjusted difference in weight gain) being 5.5 lb. Although this result cannot legitimately be assessed for statistical significance, it suggests that treatment immediately after birth may give an appreciable improvement in subsequent liveweight gain (Fig. 1).

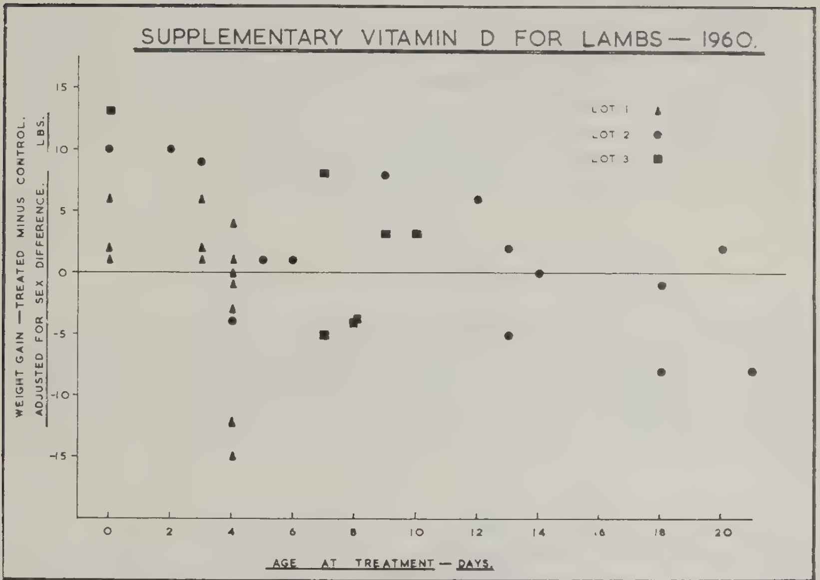


Fig. 1—Differences in weight gain between treated and control twin.

Single lambs

The joint effects on liveweight gain of treatment, sex and initial weight were investigated by regression analysis within Lot 1 and Lot 2 (Lot 3 contained only 2 single lambs and was not used). The average difference in liveweight gain between treated and control lambs, adjusted for sex and initial weight difference, was obtained as 0.21 lb. in favour of treated lambs, with a standard error of 2.25 lb. This difference does not approach significance. The effect of sex was also non-significant, so that there was no firm basis for adjusting individual results for sex differences.

DISCUSSION

In this trial no significant difference in liveweight gains between treated and control lambs were found. In the case of single lambs the overall average response, if any, was not more than 4 to 5 lb. per lamb over the experimental period. In the case of twins the corresponding figure was not more than 3 lb., i.e. not more than 5 per cent of the average final liveweight of the lambs. There is a possibility, however, that if treatment were administered in all cases immediately after birth an appreciable response in liveweight gain might be obtained, possibly of the order of 5 lb. per lamb. It is worthy of note that treatment of twins immediately after birth produced a positive response in growth rate in all three lots regardless of the actual date of treatment. Lots 2 and 3, however, included only three pairs of twins in which treatment was applied within 3 days of birth.

The average daily amount of sunshine over the ten days immediately following treatment, and over the whole of each trial period is shown (Table IV). The data were calculated from the records of the Meteorological Station at Dublin Airport (5) which is situated within 7 miles of the farms concerned. Although Lot 1 received least sunshine, especially in the first 10 days after treatment, the supplementary vitamin D_3 failed to produce a significant response in growth rate of the lambs.

TABLE IV

Average daily sunshine at Dublin Airport (hours)

	First 10 days after treatment	Over trial period
Lot 1	0.4	4.3
Lot 2	2.7	5.9
Lot 3	6.5	6.6

These results are in agreement with the findings of Ewer in Britain (6), Franklin in Australia (7), Green in Tasmania (8) and McClymont and Reis in New South Wales (9), who found that the value of supplementary vitamin D for sheep was not apparent where the animals received a normal diet. Some of these workers found the supplement to be useful where the animals were kept on a rachitogenic diet of green feed.

The data presented in this paper, however, suggest that vitamin D treatment of lambs at a very early age, or treatment of the ewes in late pregnancy might be worthy of further investigation.

ACKNOWLEDGEMENTS

The authors wish to thank the flock owners, Dr. H. Conway and Mr. W. McGrath for their wholehearted co-operation, and Mr. F. O'Carroll, Head of the Statistics Department, An Foras Taluntais, who carried out the statistical analysis of the data. Thanks are also due to Messrs. Crookes' Laboratories, Ltd., for the supply of vitamin D_3.

REFERENCES

1. N. Taylor, personal communication.
2. M. V. Jackson, personal communication.
3. Neseni, R., Altenkirch, W. and Otto, E., *Arch. Tiernahr*, **4**: 258, 1954.
4. Crowley, J. P., *Vet. Rec.*, **73**: 295, 1961.
5. Monthly Weather Reports, Dept. of Transport and Power, Meteorological Service, Dublin, 1960.
6. Ewer, T. K., *Vet. Rec.*, **62**: 603, 1950.
7. Franklin, M. C., *Austral. Vet. J.*, **29**: 302, 1953.
8. Green, R. J., *ibid.*, **29**: 316, 1953.
9. McClymont, G. L. and Reis, P. J., *Agric. Gaz. N.S.W.*, **67**: 251, 1956.

THE MARKETING OF IRISH AGRICULTURAL OUTPUT

B. Tomlin

An Foras Talúntais, Rural Economy Division,
Agricultural Marketing Division, 39 *Kildare Street, Dublin* 2

ABSTRACT

This article is a factual review of the disposal outlets for Irish agricultural output. The underlying idea was to assess quantitatively from published sources the importance of the channels into which output passed at the farmgate stage. For this purpose, the main products were taken one by one and the legislative measures and statistical data relevant to each collected. The bulk of the numerical estimates available were contained in the various publications of the Central Statistics Office, Dublin, which helped also by providing estimates of consumption on farms without process of sale. The article, then, consists of a study of each of the main products of our agricutlure, setting forth the legislative provisions affecting their marketing and the available quantitative information about their manner of disposal.

INTRODUCTION

The starting-point of this study was a suggestion that an attempt be made to get as much quantitative information as possible from published sources about the disposal of Irish agricultural output at the farmgate.

The object of investigation was Ireland's gross agricultural output defined by the Central Statistics Office (1) as "that portion of total agricultural production, which was sold off farms or consumed by persons on farms without process of sale during the year of enquiry." The year taken was 1957, the last for which the relevant statistical data were available. Important changes have taken place since then in some instances. Where this is so, reference is made to them in the text. They need not, however, detract from the validity of using 1957 for a general discussion of output disposal.

The following table outlines the area of investigation, which was pursued on a product-by-product basis with reference to three main factors—legislation, output and marketing.

The published data have had to be supplemented by estimates obtained from the Central Statistics Office of the amount of each product consumed by persons on farms without process of sale. These amounts are referred to in the text as "on-farm consumption." Apart from this, and the use of an estimate of vegetable disposal, published sources only have been used throughout. The C.S.O. does not regard these estimates of "on-farm consumption" as being sufficiently reliable for official publication and, therefore, they must be taken as indicating orders of magnitude rather than as exact figures.

TABLE I

Irish agricultural output in 1957

PRODUCT	VALUE			CONSUMPTION OF OUTPUT (Percentage of total quantity)		
	£ million	Percent	Average percentage 1955-9 inclusive	Unsold on Farms	Other Home	Export
Cattle	53.7	27.7	(26.9)	nil	16	84
Milk and Milk Products	44.9	23.2	(22.5)	11[1]	62[1]	27[1]
Pigs	18.7	9.7	(10.6)	6	68	26
Eggs	9.9	5.1	(5.9)	50	47	3
Poultry	5.1	2.6	(2.8)	31[2]	38[2]	31[2]
Sheep	8.1	4.2	(4.4)	n.a. (very small)	c.70	30
Wool	3.3	1.7	(1.6)	nil	15	85
Horses	3.1	1.6	(1.7)	nil	4	96
Total Livestock and Livestock Products	146.8	75.8	(76.4)			
Wheat	13.2	6.8	(5.6)	nil	94	6[3]
Oats	1.7	0.9	(0.9)	nil	99	1[3]
Barley	5.9	3.0	(2.9)	nil	78	22[3]
Sugar Beet	5.4	2.8	(2.7)	nil	84	16[3]
Potatoes, Cabbage, Turnips	8.6	4.4	(5.4)	53	40	7
Other Crops and Fruit	3.2	1.7	(1.3)	n.a.	n.a.	n.a.
Turf and Timber	7.9	4.1	(3.8)	90	10	nil
Other Products	1.0	0.5	(0.5)	n.a.	n.a.	n.a.
TOTAL OUTPUT (*a*)	193.7	100.0	100.0	17(*b*)	45(*b*)	37[3](*b*)

[1] Excluding farm butter, buttermilk and separated milk. [2] By weight, calculated from Table X and CSO estimate. [3] 1958 exports of wheat, barley, oats and sugar beet, as the products of the 1957 harvest were not exported until 1958.
(a) Exclusive of changes in livestock numbers, (b) Percentage of value of total output.

It should be borne in mind that export values from agricultural output figures will differ from those taken from external trade figures (see especially Table XII), firstly because in the former case, they include the content of the agricultural product in processed goods exported, and secondly because they are valued at agricultural prices, whereas external trade figures show them at export prices, e.g., the export of horses in 1957 is valued at £2,990,000 in reference (4) whereas reference (6) gives the value as £3,548,575.

Source: Reference (1, 2).

CATTLE AND SHEEP

In 1957 (admittedly an exceptional year for cattle exports), cattle and sheep accounted for 32 per cent of agricultural output, and for nearly 45 per cent of total exports (3). Since then, the eradication of bovine tuberculosis in Great Britain has curtailed exports of store cattle and necessitated more regulation of the trade. The principal measures affecting it are the Slaughter of Cattle and Sheep Acts, 1934-36, the Slaughter of Animals Act, 1935, the Agricultural Produce (Fresh Meat) Acts, 1930-38, the Agricultural Produce (Meat) (Miscellaneous Provisions) Act, 1954, and the Diseases of Animals Act, 1957.

The first four Acts are mainly veterinary provisions governing the slaughtering process. They also restrict entry into the meat trade by confining slaughter and manufacture of cattle products to licensees, and the export of these products to

licensed or permit-holding proprietors of premises registered for slaughter and export. The most far-reaching measure has been the Diseases of Animals (Bovine Tuberculosis) Act of 1957 enacted to rid the country of that disease, and thus to safeguard our live cattle trade with Britain. Under this Act, clearance areas have been established into which it is illegal to move untested or tubercular cattle. In addition, tested and untested cattle must be marketed and transported separately. The financial provisions in the Act regarding the disposal of reactor cows, the Scheme of Guaranteed Payments for fat cattle exports, and the fact that Britain is free of bovine tuberculosis have had a great effect on the relative importance of the different elements in our cattle trade.

TABLE II

Manner of disposal of cattle and sheep

	CATTLE 1956	1957	1960		SHEEP 1956	1957	1960
Home consumption and changes in stocks of tinned meat	177[1]	180	186		796[1]	810	1,006
Export: as fresh, chilled or frozen beef	78	149	286	as mutton and lamb	257	191	507
as tinned beef or other	77	58	76				
as fat cattle	180	78	220	as fat sheep	39	23	39
as store cattle	488	747	317	as store sheep	75	82	165
as milch cows, calves, etc.	6	6	5	as lambs	56	55	106
	1,006	1,218	1,090		1,223	1,161	1,823

1 = All figures in thousands.
Imports of 13,000, 113,000 and 45,000 cattle in 1956, 1957 and 1960 (over 99 percent from Northern Ireland) must be subtracted from these figures to get cattle output. Imports of 240,000 sheep must be subtracted from the 1960 figures to get sheep output.
Source: Reference (1, 4, 5, 6, 7, 8).

From Table II, it is apparent that figures for 1957 were not representative of the cattle export trade. In addition to demonstrating the great changes which have taken place since then within the trade, the table illustrates the difference between the sheep and cattle trades and the continued expansion of the sheep industry.

The traditionally great importance of the live export trade was extremely pronounced in 1957, when over two-thirds of all cattle sold off Irish farms were shipped live. Most of them were store cattle, which were shipped either to Great Britain (504,000) or Northern Ireland (242,000) (6, 9). There has since been a marked drop in live cattle exports caused by the falling-off of store shipments. The vast bulk of our exports, however, still goes to the United Kingdom. The importance of store cattle exports was traditional and was reinforced by the fact that Irish store cattle fattened in Britain qualified for inclusion in the British Fatstock Guarantee Scheme. Their decline, which was especially marked in 1960, was caused by the reluctance of British buyers to deal in them, as they must be kept segregated on their farms unless fully attested. In addition, the depression in the market for beef in Britain for the past year has affected store prices very adversely.

Irish legislation has also helped to alter the pattern of exports. The subsidy on reactor cows delivered to meat factories has enormously increased the supply of basic material (mostly cows), with a consequent rise in dead meat exports. A Scheme of Guaranteed Payments under which exporters of fat cattle and their carcase meat receive a bounty, has helped to maintain cattle prices and to increase exports of fat cattle rather than stores. It is too early to say if these changes will be a permanent feature of our export trade, or if they will lapse with the eradication of bovine tuberculosis.

The trade in sheep, although conducted and organised like the cattle trade, did not show a similar pattern in 1957. Home consumption was the major factor, and live exports were not as important as in the cattle trade, although store sheep exported qualified for the British Fatstock Guarantee Scheme subsidy in the same way as store cattle. Since then, while the growth in exports of sheep in carcase form has kept pace with that of beef exports, the numbers of cattle and sheep exported live have varied inversely, the dramatic fall in store cattle exports compared with fat cattle being matched by an equally striking rise in exports of store sheep and lambs.

The ultimate outlets for our cattle and sheep fall into three categories, home consumption, live export and dead meat export, each largely served by a different group of marketing agents—wholesale and retail butchers, live cattle exporters and licensed meat exporters, respectively.

It can be calculated from Table II that slaughter for consumption in Ireland accounted for fifteen per cent of the cattle and seventy per cent of the sheep slaughtered in 1957 (on-farm consumption was practically nil). This meat was sold by about 1,800 retailers of fresh meat. The results of a census of retailers in 1956 and of a sample inquiry in 1957 are shown in Table III.

TABLE III

Purchases by retailers of fresh meat
(Included in the Census of Distribution)

Area	Total number of shops (1956)	Number in census (1956)	Purchases (£ million) 1956	1957
Dublin and Dun Laoire	466	369	4.6	4.6
Rest of Leinster	414	331	2.3	2.5
Munster	564	416	2.3	2.4
Connaught and part of Ulster	330	245	1.0	0.9
	1,774	1,361	10.2	10.4

The difference between the above figure for purchases in 1957 and the value of cattle and sheep slaughtered for home consumption as given in the agricultural output figures (about £15,500,000) is accounted for mainly by the fact that not all the butchers' shops were included in the Census and also by differences in the basis of valuation, slaughter by institutions, and by sales of tinned meat.
Source: Reference (10, 11).

The live export trade accounted in 1957 for 68 per cent of cattle disposals and 14 per cent of sheep disposals. The shipments were made mostly free of legislative regulation, by an indeterminate number of exporters. The fact that exports of cattle

to countries other than the United Kingdom needed a licence was not important since these countries accounted for only 4 per cent of shipments in 1957 (12).

Dead meat exports, which in 1957 accounted for 17 per cent of cattle and 16 per cent of sheep sales, are more regulated and concentrated. There were in 1957 seventy licensed exporters of carcase meat, fifty-six of whom were actively engaged. The majority worked on a small scale as 90 per cent of shipments of carcase meat were made by only seven licensees in 1958. There were seventeen licensed exporters of canned meat in 1957, most of whom were licensed to export carcase meat also. Only thirteen of them were active and five of them accounted for 85 per cent of the shipments (13).

While the ultimate outlets for cattle and sheep are clear, the methods of disposal at the farmgate stage are not so distinct or easily traced. Most sales are effected at fairs or marts, of which there were about three hundred and fifty (14) and eighty (15), respectively, in 1960. No estimate can be offered of the numbers of cattle and sheep disposed of by farmers at fairs or at marts, nor is it possible to indicate the proportion sold on farms. The degree of intervention by middlemen, one of the most interesting questions in cattle marketing, is also incapable of quantitative assessment.

MILK AND MILK PRODUCTS

Milk and its products constituted 23 per cent of agricultural output in 1957. The uses to which it was put are shown in Table IV. Total sales off farms were 374.4 million

TABLE IV

Utilization of milk output in 1957 (millions of gallons)

Liquid Milk:	consumed unsold on farms	44.4	
	other liquid consumption	74.9	
			119.3
Used in Industry:	for creamery butter	249.4	
	for other products	50.1	
			299.5
			418.8

Source: Reference (1).

gallons, sales for liquid consumption accounting for 20 per cent and sale to industry for 80 per cent of the total (67 per cent for butter and 13 per cent for other products). Since their disposal and statutory regulation are different, milk for liquid sale and for use in industry, farm butter and other products will be treated separately.

Liquid Milk

Seventy-five million gallons of milk were sold in 1957 for liquid consumption, about 30 million gallons being consumed in Dublin and Cork (16), leaving forty-five million gallons for consumption elsewhere. In addition, 44 million gallons were con-

sumed unsold on farms. The production and sale of milk for liquid consumption is governed by the following Acts:—the Sale of Food and Drugs (Milk) Acts, 1935-36; the Milk and Dairies Acts, 1935-56; and the Milk (Regulation of Supply and Price) Acts, 1936-52.

The Sale of Food and Drugs (Milk) Acts, 1935-36, provide that milk for liquid sale must have a fat content of not less than 3 per cent and a solids non-fat content of 8.5 per cent. The Milk and Dairies Acts, 1935-56, are concerned mainly with safeguarding public health and apply to the whole country. They confine the production and sale of milk for human consumption to registered persons. Anyone wishing to sell milk other than on a premises, e.g. from a vehicle, must have a licence to do so. The production and sale of milk under special designation (e.g. as pasteurised milk) or the bottling of milk, even under general designation, must also be licensed. The Milk (Regulation of Supply and Price) Acts 1936-52 apply only in the Dublin and Cork areas. They stipulate that, in addition to being registered under the Milk and Dairies Acts, producers and sellers of milk in these areas must be registered with the Dublin or Cork Milk Boards and that, with few exceptions, milk may be offered for resale only under contract by registered producers to registered distributors. The Boards also recommend to the Minister for Agriculture the minimum wholesale prices payable to producers. The Minister for Agriculture fixes minimum wholesale prices (not necessarily those recommended) and the maximum retail price is fixed by the Minister for Industry and Commerce.

Being so closely regulated by these legislative measures the marketing of liquid milk is easy to describe. In the Dublin and Cork areas, registered producers sell mostly under contract to registered distributors at a guaranteed price. The distributors may be retailers or wholesalers (including bottlers) who resell to consumers on a fixed price basis. Elsewhere registered dairymen sell either to consumers or to distributors, who must also be registered dairymen. There is no statutory contract or fixed-price basis for these sales, but in general prices follow those in Dublin and Cork fairly closely.

Milk for Industry

In 1957, 299.5 million gallons of milk were sold for use in industry. This milk was produced by about one hundred thousand farmers mainly in Munster and South Leinster. These areas accounted for 70 per cent of the farms, 80 per cent of the cattle and 90 per cent of the milk produced (17). This was sold subject to the provisions of the Dairy Produce Acts 1924-47, the Creamery Acts, 1928-34 and the Dairy Porduce (Price Stabilisation) Acts, 1935-56. Legislation to set up a board (An Bórd Bainne) for the better export marketing of dairy produce has recently been enacted under the title The Dairy Produce Marketing Act, 1961. The Dairy Produce Acts, 1924-27, have as their object the regulation of the quality of the milk intake, the methods of manufacture and the quality of the finished products. In securing these ends, they affect the marketing of milk directly by stipulating that creameries, separating stations, butter factories and non-manufacturing exporters be licensed, that, with few exceptions, butter may be made at creameries only from cream separated on the premises or supplied by a separating station, and that milk must be bought on its butter-fat

content. The Creamery Acts 1928-34 provide for the re-organisation of the dairy industry and its concentration in more viable units. This has been done chiefly by the acquisition of uneconomic creameries by the Dairy Disposal Company.

The Dairy Produce (Price Stabilisation) Acts 1935-56 provide for a minimum price for butter (and thus for milk) by the workings of the Butter Marketing Committee, which guarantees to buy butter from creameries at a specified price. For this purpose, it imposes a storage levy (passed on to consumers) and an "export loss" levy (on milk producers) and receives a government subsidy. The Dairy Produce Marketing Act, 1961, has substituted An Bórd Bainne for the Committee and given it power to control and improve exports. It will buy butter at a fixed price (and sell within the State at a fixed price), and receive a government grant to cover two-thirds of any loss sustained in exporting. In addition, it will impose on creameries milk and butter levies and will collect a butter stocks levy from producers and traders.

These legislative measures regulate the marketing of milk for use in industry so closely that it is easily described. It is sold directly by the producers to registered creameries or separating stations. There were a hundred and fifty-nine and four hundred and thirty-five of these respectively in 1957 (18), and all were owned by co-operative societies or by the Dairy Disposal Company, since government policy has confined the trade to these two categories of owner. They pay for milk on its butter-fat content and, since the price of butter guaranteed by the Butter Marketing Committee (in future An Bórd Bainne) controls the price of their products, they pay a fairly uniform price. The products made from this milk are shown in Table V.

TABLE V

Industrial use of milk in 1957

Product	Number of creameries engaged	Quantity of milk used (millions of gallons)
Creamery Butter	157	248.8 (80.9)
Cheese	16	6.0 (0.1)
Processed Cheese	2	
Milk Powder	4	4.6 (2.9)
Chocolate Crumb	7	21.5 (20.6)
Condensed Milk	1	0.9 (0.08)
Whey Butter	1	Not known
Casein	1	Not known
Lactose	1	Not known
Malted Milk	1	Not known
Cream	Not known	6.1 (3.2)

The figure for creamery butter differs in Tables V and IV because that in Table IV is a revised figure. The figures in parentheses represent the milk equivalent in millions of gallons of the exports of these products.
Source: Reference (19, 20).

Most of the chocolate crumb manufacturers are organised under the Companies Acts and are affiliated with firms in Britain to whom they sell the product. Condensed milk is made by the Dairy Disposal Company, and malted milk by a company organised under the Companies Acts. All the other activities mentioned in Table V are engaged in by creameries in addition to butter-making.

Farm Butter

The quantity of farm butter made is calculated by the Central Statistics Office by subtracting the amount of milk with known uses from the estimated total quantity of milk produced. Revised figures for 1957 give output as 384,000 cwt. made from 112.6 million gallons of milk (1). No figures are available from which an estimate of the manner of disposal of this item can be made.

Buttermilk and Separated Milk

There was an estimated output of 51 million gallons of these products in 1957 (1). This figure represents the estimated on-farm consumption in that year.

PIGS

Pigs account for about 10 per cent of our agricultural output and are an important adjunct to the dairy industry. They make a worthwhile contribution to the small farmer's income, as well as being a useful means of utilising skim milk. Total output of pigs in 1957 amounted to 1,241,000 valued at £18,670,000, and was divided between home consumption and export in the approximate ratio of 3:1 (1). There were four main outlets, shown in Table VI.

TABLE VI

Disposal of pigs in 1957

Purchases by bacon factories	1,116,246 (88,830 for pork)
Purchases by pork butchers and by-product manufacturers	44,067
Live exports	187
Consumed unsold on farms	80,500
	1,241,000

Purchases by pork butchers are obtained here by subtracting the other figures from total output.
Source: Reference (1, 6, 21).

Pigs are sold subject to the Pigs and Bacon Acts, 1935-56. These Acts confine slaughtering of pigs, bacon-curing and the export of pigmeat to licensees. Purchases and sales by these licensees are regulated by the Pigs and Bacon Commission as follows:—pigs bought on a dead-weight and grade basis are divided into classes and grades; those grading "A" Special, "A," and "B.1" are bought at fixed minimum prices. Bacon producers are guaranteed a minimum price for grade "A" and "Extra Selected" bacon exported, but other grades of bacon exported get no support. Factories may be compelled to export a specified maximum amount of their grade "A" production. The Commission finances its activities out of funds maintained by levies and government subsidy. A new Bill, reconstituting the Commission and giving it wider powers to export and to regulate and promote the export of bacon was enacted this year under the title "The Pigs and Bacon Act, 1961."

Purchases by bacon factories account for 96 per cent of pigs sold and are the predominating factor in the trade (Table VI). In 1957, a total of 38 bacon factories controlled by 30 firms were in operation (out of 41 licensed). Thirty-three of these factories were licensed to export pork and bacon. There were also four factories licensed to export only pork (22).

Of the purchases by these factories, 868,824 pigs (78 per cent of their purchases) were bought on a dead-weight and grade basis. The classification and grading of these pigs is shown in Table VII.

TABLE VII

Grading of pigs purchased by bacon factories in 1957

Carcases of Baconers (120-140 lb.)[1]			Carcases of Baconers (141-147 lb)[2].		
Grade	Number	Percent	Grade	Number	Percent
A	558,632	67.2	B.1	12,834	34.6
B	172,227	20.7	B	11,492	31.0
C	73,933	8.9	C	9,842	26.5
X	26,943	3.2	X	2,291	7.9
Total	831,735	100.0	Total	37,089	100.0

1 = Equivalent to c.1.0.8 to c.1.2.0
2 = Equivalent to c.1.2.1 to c.1.2.7
The classification weights and grading basis have since been altered, the latter by the introduction of the grade "A Special." As a result of these measures and improvement in the quality of pigs, the percentages quoted have also changed.
Source: Reference (23).

A total of 571,466 pigs (Grades A and B.1), almost 50 per cent of total pig sales off farms, were bought by bacon factories on a guaranteed minimum price basis. Factories buy in any of the following ways, the importance of which cannot be estimated quantitatively (though purchase from producers deadweight and grade is the most common):—

(*i*) direct from producers: dead-weight and grade; at fairs live, judged by eye; or at marts or factory scales by liveweight;

(*ii*) through agents who buy from farmers and dealers by sight at farms and fairs, or by weight at marts or agents scales;

(*iii*) from dealers who buy live at sight on farms or at fairs, or by weight at marts. Dealers sell in turn to agents, or factory bidders, or at the factory.

EGGS

In this country production of eggs is normally a small-scale marginal enterprise. Eggs accounted for about 5 per cent of total agricultural output in 1957. Their output is calculated by adding to estimated on-farm consumption, five-fourths of the numbers acquired by registered wholesalers and dealers (which are taken to represent 80 per cent of sales off farms). Table VIII shows output in 1957.

TABLE VIII

Output of eggs in 1957

Type	Home[1]	Export[1]	Total[1]	Home[2]	Export[2]	Total[2]
Hen	6,434	231	6,665	9,384	336	9,720
Duck	318	1	319	464	1	465

1 = great hundreds (120) x 1000
2 = in £1000's
These figures were later revised downwards, but as the revised figures do not break down exports into hen eggs and duck eggs, the unrevised figures are used here.
Source: Reference (4)

An estimated 3,500,000 great hundreds (i.e. units of 120) of eggs were consumed unsold on farms in 1957. Approximately another 3,500,000 great hundreds were therefore sold off farms of which 80 per cent were sold subject to the provisions of the Agricultural Produce (Eggs) Acts, 1939-55. These Acts provide that dealers, wholesalers and preservers of eggs must be registered while retailers may be called on to do so. Export of eggs is confined to registered wholesalers, and the home market is regulated as follows:—producers may sell to wholesalers, dealers, retailers or consumers; wholesalers may buy eggs only from producers or dealers or, under licence, from other wholesalers; dealers may buy only from producers unless exempted by licence; they may sell in turn to only wholesalers or they may themselves under licence sell by wholesale or retail.

It follows from the basis of output calculation that 80 per cent of eggs sold were acquired in 1957 by registered dealers and wholesalers, who numbered 3,108 and 206 respectively. The remaining 20 per cent (about 700,000 great hundreds) were probably sold direct by producers to consumers and retailers. In general, eggs are bought at the farm or the purchaser's premises at unregulated prices. Although empowered to do so, wholesalers do not buy from producers or dealers on a quality basis. This is understandable since the trade is very seasonal (80 per cent of output takes place between February and July (24), and since so many of them work on a small scale (Table IX) with a consequent disadvantage in any attempt to discriminate in their prices to suppliers.

TABLE IX

Acquisition of eggs by wholesalers in 1957

Number of cases bought	Number of wholesalers
Less than 1,000 each	62
1,001—2,000 each	52
2,001—3,000 each	17
3,001—5,000 each	35
5,001-10,000 each	25
More than 10,000 each	9

Source: Reference (25)

POULTRY

Poultry production, like that of eggs, is normally a small-scale farmyard activity, as there were only an estimated few dozen broiler enterprises producing about a million birds in 1957 (26). Output in that year accounted for less than 3 per cent of total agricultural output, made up as shown in Table X.

TABLE X

Output of poultry in 1957

	QUANTITY				VALUE		
Type	Home number (000)	Export number (000)	Total number (000)	Approximate total weight (a) (000 cwt.)	Home £000	Export £000	Total £000
Turkeys	433	662	1,095	120	958	1,465	2,423
Geese	457	101	558	70	505	112	617
Duck	486	19	505	17	175	7	182
Fowl	5,128	1,444	6,572	220	1,959	552	2,511
				427			

These figures were later revised downwards, but as the revised figures do not give details for poultry other than turkeys, the unrevised figures have had to be used.
(*a*) Estimate.
Source: Reference (4)

In 1957, an estimated 160,000 cwt. of poultry were consumed unsold on farms, and 267,000 cwt. were sold subject to the Agricultural Products (Fresh Meat) Act, 1930, and the Agricultural and Fishery Products (Regulation of Export) Act, 1947. The former act gives the Minister for Agriculture power to regulate the packing of poultry and dead rabbits, the latter forbids the export of poultry and rabbits except under licence.

Sixty per cent of the output of turkeys was exported, mainly to Britain for Christmas. Export is confined to licensed packers who, being large wholesalers, probably also secure a good part of the home market. In 1958, there were 42 annual and 69 seasonal licensees active, and fourteen of the former accounted for 45 per cent of exports (27). It is unlikely that they had as a big a percentage of the trade in geese, ducks and other fowl. They did, however, handle a great amount of the products as export was confined to them, and being wholesalers, they probably had a good share of the home market, especially as they are likely to have handled many broilers (none of which were exported).

Turkeys are sold to dealers or packers at farms or fairs, often at a flat rate per pound for a producer's total poundage. They are not subject to price or quality control at this stage, even though there is strict quality control of turkey exports. Other poultry is bought in the same way, although it is unlikely that a producer's entire output is bought at a flat rate, since the trade is much less seasonal than that in turkeys.

WOOL

Wool represented less than 2 per cent of the value of our agricultural output in 1957. Only clipped wool is counted, as wool processed by fell-mongers from skins bought from slaughterers is regarded as being industrially produced.

Output of shorn wool in 1957 was 14,988,000 lb. (1), none of which was consumed on farms. Very little was used by Irish manufacturers, as exports of raw clipped wool amounted to 12,453,500 lb. (6). The trade in wool is not regulated by law and sales off farms must have been mainly to merchants for export. About one million pounds were sold in 1959 through the National Farmers Association Marketing Scheme at a hundred centres in twenty-three counties (28). Three contractors were appointed who bought clean wool on a grade basis from National Farmers Association members, who guaranteed to have 9,000 lb. of wool available at each sale.

HORSES

Horses accounted for only 1.6 per cent of total agricultural output in 1957. Almost all the output was exported (only one thousand out of a total of twenty-three thousand horses were for home use). During that year the sale of horses was unaffected by legislation. Since then, however, an Act has been passed which will, after a certain date, forbid the export of live horses for slaughter (at present allowed under permit), and ensure that all subsequent exports will be in the form of horsemeat from licensed horse-slaughtering premises.

TABLE XI

Export of horses in 1957

Destination	Number	Value (£)	Approximate unit value (£)
U.S.A.	234	446,446	1,900
Great Britain	4,120	2,036,657	490
France	1,908	152,404	80
Belgium	10,939	604,150	55
Northern Ireland	4,205	146,517	35
Other Countries	1,080	162,401	150
Total	22,486	3,548,575	

Source: Reference (12)

In 1957, there were three distinct export markets for Irish horses. The first (the U.S.A. and Great Britain) and most important by value, was for high priced animals, i.e. bloodstock for racing and breeding, and hunters. The second (Belgium and France) was the most important in terms of numbers exported, the demand being for cheaper horses shipped live for slaughter and sale. This trade will shortly be replaced by a

trade in dead meat. The third market (Northern Ireland) was probably confined to draught horses, as the average price per head was low and there is no demand there for horsemeat.

With regard to the actual marketing of horses, the higher-priced animals are bought by private owners or agents, either at the breeders' premises or at bloodstock sales while the cheaper types are bought at farms or fairs by dealers and exporters.

CEREALS

In 1957, cereals (wheat, barley and oats) accounted for about 11 per cent of the total value of agricultural output. The output of cereals was calculated in the following manner by the Central Statistics Office:—

(*i*) Wheat: by the addition of returns made by proprietors of flour mills, wheatenmeal mills, permit mills and distilleries (on-farm consumption and sales of wheat for seed were therefore excluded).

(*ii*) Oats: by the addition of the amounts exported and used by millers and manufacturers of animal feeding-stuffs, as well as the estimated quantities consumed by non-agricultural horses and milled on commission.

(*iii*) Barley: by the addition of purchases made by brewers, malsters, distillers and manufacturers of animal feeding-stuffs.

TABLE XII

Output of cereals in 1957

	QUANTITY				VALUE	
Crop	Home (000 cwt.)	Export (1958) (000 cwt.)	Total (000 cwt.)	Home (£000)	Export (1958) (£000)	Total (£000)
Wheat	8,596	515	9,111	12,695	517	13,212
Oats	1,652	26	1,678	n.a.	n.a.	1,741
Barley	3,972	1,095	5,067	4,425	1,487	5,912

Exports are taken for 1958, as it was in that year that most of the products of the 1957 harvest were exported. Wheat and oats exported are valued at export, not agricultural, prices. Most of the barley exports consist of the barley content of other products, e.g., beer.
Source: Reference (1, 29).

All cereals are sold subject to the Agricultural Produce (Cereals) Acts, 1935-58, which are now enforced only in the case of wheat. Trade in wheat is regulated and millers must have a licence or permit to grind, while millers, importers and distillers must be registered. Milling quotas are fixed for each mill and a percentage of that quota must be home-grown millable wheat. Wheat is purchased by millers on a grade and classification basis, a minimum price applying to each class and grade as indicated in Table XIII.

TABLE XIII

Grading, classification and prices of wheat in 1960

BUSHEL WEIGHT (lb.)	MOISTURE CONTENT 22 per cent or less	22-25 per cent	25-26 per cent
	Price per barrel s. d.	Price per barrel s. d.	Price per barrel s. d.
64 or greater	78 6	76 0	73 6
Less than 64 but more than 63	77 6	75 0	72 6
„ 63 „ 62	76 6	74 0	71 6
„ 62 „ 61	75 6	73 0	70 6
„ 61 „ 60	74 6	72 0	69 6
„ 60 „ 59	73 6	71 0	68 6
„ 59 „ 58	72 6	70 0	67 6
„ 58 „ 57	71 6	69 0	66 6
„ 57 „ 56	70 6	68 0	65 6
„ 56 „ 55	69 6	67 0	64 6
55 or less	68 6	66 0	63 6

Source: Reference (30).

If millers buy through agents, they must pay the agents (who must be licensed) a fixed commission per barrel. An Bórd Gráin disposes of surplus wheat imposing levies and receiving a government subsidy for that purpose. An attempt is made to show the manner of disposal of cereals in 1957 in Table XIV.

TABLE XIV

Estimated disposal of output of cereals in 1957

Method of disposal	No. of establishments	Wheat cwt.	Oats cwt.	Barley cwt.
Flour mills	35	8,685,000	37,500	397,600
Other mills and animal feed manufacturers	121 large, 33 small	301,000	837,260	1,877,900
Brewers	9			1,351,000 (*a*)
Malsters	31			715,000 (*b*)
Distillers	7			128,000
Consumed by non-agricultural horses			*c*.740,000 (*c*)	
Milled on commission for farmers			*c*. 60,000 (*c*)	
		8,986,000	*c*.1,674,760	4,469,500

(*a*) October, 1956 to September, 1957. (*b*) August, 1957 to 1958. (*c*) Estimate.
The totals in this table differ from those in table XII because of differences in calculation caused by imports and varying accounting-years.
Source: Reference (21, 31).

Wheat, oats and feeding-barley are sold either direct or through merchants by farmers to flour millers or other mills. Wheat is sold at a fixed price (Table XIII) and most intermediaries are licensed agents of the mills, receiving a fixed commission. There is no fixed price for feeding-barley, but a sort of "gentleman's agreement" operates whereby compounders of animal feed agree to pay not less than a certain price to anyone selling to them. Most of the malting barley is grown for one firm of brewers (Messrs. Guinness) who also buy some feeding-barley for roasting. They appoint agents from whom they contract to buy a quota of barley, provided the agents pay growers not less than a certain price agreed between the Sugar Beet Growers' Association and Messrs. Guinness. The agents then contract to buy a sub-quota of barley at the specified price, from growers.

SUGAR BEET

All sugar beet is sold to Comhlucht Siúicre Éireann Teo (Irish Sugar Company Ltd), whose ordinary capital is contributed by the State and whose preference and debenture capital is available to the public. It is the sole manufacturer of sugar in Ireland. Sugar beet output was 795,000 tons in 1957. Virtually no refined sugar was exported, but the sugar content of other exports in 1958 (made from the product of the 1957 beet harvest) was equivalent to 131,000 tons of beet (1). The acreage to be grown is agreed between the Company and the Beet Growers Association, and the output is bought directly from growers at the four factories of the Company on the basis of an agreed price, which varies with the sugar content of the beet.

TURF AND TIMBER

Output of turf and timber is the amount estimated to have been drawn from bogs and cut down by farmers. In 1957, 2,590,000 tons of turf together with timber valued at £125,000 were produced. An estimated 2,400,000 tons of turf and timber were consumed unsold on farms, the timber constituent of which was very small, as the ratio of turf to timber output by value in 1957 was 60:1 (1). The remaining small quantity of turf was sold either to the Electricity Supply Board, which buys agriculturally produced turf in some areas, or locally to fuel merchants or consumers.

FRUIT AND VEGETABLES

The Central Statistics Office estimates fruit output by applying a value per acre to the acreage under fruit reported in its enumeration of crops every June. In 1957, 12,300 acres (32) produced fruit valued at £786,000 of which £43,000 worth was exported (4). Since no distinction is made between purchases of home-produced and imported fruit in either the Census of Industrial Production or the Census of Distribution, no purpose

would be served by showing purchases by confectioners, canners and fruit retailers. No quantitative estimate can be offered, therefore, of the manner of disposal of our fruit output. The output of potatoes, turnips, cabbage and of "other crops" in 1957 is shown in Table XV.

TABLE XV

Output of vegetables in 1957

	QUANTITY			VALUE		
Vegetable	Home (000 tons)	Export (000 tons)	Total (000 tons)	Home (£000)	Export (£000)	Total (£000)
Turnips	36	—	36	107	—	107
Cabbage	106	—	106	1,479	—	1,479
Potatoes	483	50	533	6,371	676	7,047
Other crops	—	—	—	?	?	2,450

Export figures for "other crops" are not quoted, as the export-category "other crops" does not correspond exactly to the output-category "other crops" in reference (2). However, the vegetable content (apart from mushrooms) was not large, total vegetable exports in 1957 at export prices being valued at only £70,000 (6). Mushroom exports amounted to £146,000 (6).
Source: Reference (1, 2).

In Table XVI a more detailed estimate is given of the manner of disposal of potatoes, the most important of these vegetables. Sixty-three per cent of the potatoes

TABLE XVI

Estimate of disposal of output of potatoes in 1957

	000 tons		per cent
Purchases by alcohol factories	12		
Exports (seed and ware)	50		
	—	62	12
Consumption in towns and villages		173	33
On-farm consumption		298	56
Total output		533	

The percentages do not total 100 due to rounding-off.
Source: Reference (21, 33).

consumed by humans was accounted for by on-farm consumption in 1957, if Table XVI is correct. According to the Household Budget Inquiry of 1951-52, a total of 139,931 households in Dublin and Dún Laoire consumed an average of 21.48 lb. of potatoes each per week, giving a total annual consumption of 69,776 tons. Towns and villages outside Dublin had 177,334 households, each of which consumed 24.98 lb. per week, giving a total consumption of 102,835 tons per year. These represent 15 and 22 per cent respectively of the total human consumption of potatoes. There were changes in population between 1951-52 and 1957, which might necessitate alteration of these figures, but as there are no estimates of per-household consumption available later than those in the Household Budget Enquiry, they have been allowed to stand.

In view of their affinity in use, it is probable that the pattern of disposal in the case of cabbage and turnips is similar to that shown for potatoes used for human consumption.

The category "other crops" in the Central Statistics Office output data is here assumed to include vegetables other than potatoes, turnips and cabbage. A reliable unofficial estimate gives the value of vegetables other than those mentioned at £1,500,000, of which 35 per cent was derived from local sales, 30 per cent from sales in Dublin, 25 per cent from sales to canners and 10 per cent from other sales, e.g., for export, freezing, etc. The difference (£950,000) between this and the official estimate of "other crops" in Table XV is accounted for by the fact that the latter includes on-farm consumption, mushrooms, tomatoes and some non-vegetable crops. On-farm consumption is unlikely to account for more than 15-20 per cent of the total output, as the vegetables in question are, for the most part, grown for sale.

Assuming that the foregoing assumptions for "other crops" are correct and that the pattern of disposal in the case of cabbage and turnips approximates to that of potatoes used for human consumption, Table XVII should give a fair picture of the outlets for vegetables.

TABLE XVII

Estimated manner of disposal of vegetables in 1957

(approximate percentage of total output)

Vegetable	On-farm consumption	Local sale	Dublin	Other Outlets
Potatoes	56	19	13	12
Turnips, Cabbage	63	22	15	—
Other Vegetables	15	30	25	30

This table does not include mushrooms, tomatoes and other horticultural produce grown under artificial conditions.
Source: Estimate based on information in text.

Local sales of vegetables are made at markets or direct to consumers, retailers or wholesalers. In Dublin, many sales are made at the Corporation Market by auction to wholesalers and retailers. Other sales are mainly to canners, and since sixteen of the twenty firms engaged in canning have contracts with growers, the bulk of sales to canners are made on a contractual basis. Export of potatoes is confined to licensed exporters by the Agricultural Produce (Potatoes) Act, 1931, which controls quality very strictly. There were 3,084 export premises registered in 1957 (18).

CONCLUSION

It was stated in the introduction that the intention was to assemble quantitative estimates of the disposal of our agricultural output at the farmgate stage. Although a good deal of information has been collected, it is obvious that in many instances we have little published information of the distributive process at that point. This gap in

our knowledge is not a matter of academic interest only, inasmuch as the availability of fact is the best guarantee that both misguided decisions and misguided criticism will be avoided in this most important and much discussed field. It is hoped that the present article, setting out the knowledge available to us at the moment, will also enable us to see the points at which further information is required.

ACKNOWLEDGEMENTS

The author wishes to thank Mr. E. A. Attwood of the Rural Economy Division, and Dr. R. O'Connor of the Central Statistics Office for their assistance. The help of the library staff of the Department of Agriculture is also gratefully acknowledged.

REFERENCES

Where information given is not contained in the reference quoted, it is based on unpublished Central Statistics Office estimates, included previously in the article or calculated from information given in another form in the article.

1. *Irish Trade J. and Stat. Bull.*, Dublin, Central Statistics Office, **34**: 76, 1959.
2. *Ibid.*, **35**: 82, 1960.
3. Advisory Committee on the Marketing of Agricultural Produce, Report on the Export of Livestock and Meat, Dublin, The Stationery Office, page 1.
4. *Irish Trade J. and Stat. Bull.*, **33**: 76, 1958.
5. *Trade Stat. of Ireland*, Year and December 1956, page 18 (Table VII).
6. *Ibid.*, Year and December 1957, page 18 (Table VII).
7. *Ibid.*, Year and December 1960, page 20 (Table VII) and supplement to issue.
8. *Irish Trade J. and Stat. Bull.*, **36**: 78, 1961.
9. *Ibid.*, Year and December 1957, page 35 (Table XVI).
10. *Irish Trade J. and Stat. Bull.*, **33**: 165, 1958.
11. *Ibid.*, **34**: 95, 1959.
12. *Trade Stat. of Ireland*, Year and December 1957, page 34 (Table XV).
13. Advisory Committee on the Marketing of Agricultural Produce, Report on the Export of Livestock and Meat, pages 4 and 5.
14. *Purdon's Almanac*, Dublin, 1961, page 95.
15. Nat. Farmers' Assoc., Dublin, Yearbook 1960, 98.
16. Central Statistics Office estimate.
17. Ministerial Committee for Agriculture and Food, CSA (59) 14, Part II, OEEC, Paris, 1960, 229.
18. *Stat. Abs. of Ireland*, 1958, Dublin, The Stationery Office, page 96 (Table 85).
19. Ministerial Committee for Agriculture and Food, CSA (59) 14, Part II, OEEC, Paris 1960, 236.
20. Advisory Committee on the Marketing of Agricultural Produce, Report on the Export of Dairy Produce, Dublin, The Stationery Office, page 2.
21. *Irish Trade J. and Stat. Bull.*, **34**: 258, 1959.
22. Advisory Committee on the Export of Agricultural Produce, Report on the Export of Bacon and Other Pigmeat, Dublin, The Stationery Office, page 1.
23. Pigs and Bacon Commission, Dublin, Report of Proceedings, 1957, page 12.
24. Advisory Committee on the Marketing of Agricultural Produce, Report on Shell Eggs and Liquid Egg, Dublin, The Stationery Office, page 1.
25. *Ibid.*, page 7.
26. *Ibid.*, Report on the Export of Poultry other than Turkeys, page 2.
27. *Ibid.*, Report on the Export of Turkeys, page 3.
28. *Nat. Farmers' Assoc.*, Dublin, Yearbook 1960, 63.
29. *Trade Stat. of Ireland*, Year and December 1958, page 21 (Table VII).
30. Wheat Order, 1960, Dublin, The Stationery Office, First Schedule (S.I. 148 of 1960).
31. *Irish Trade J. and Stat. Bull.*, **35**: 103, 1960.
32. *Stat. Abs. of Ireland*, 1958, page 64-65 (Table 51).
33. Estimate based on Household Budget Inquiry, 1951-52, Dublin, The Stationery Office, 1954, XXVI, 99.

EFFECTS OF HEAVY APPLICATIONS OF NITROGEN ON THE COMPOSITION OF HERBAGE

Eilish Conroy

An Foras Taluntais, Soils Division, Johnstown Castle, Wexford

ABSTRACT

Heavy applications of sulphate of ammonia to grassland caused an increase in the total sulphur, nitrate and manganese content of herbage. These findings are discussed in relation to unpalatability of herbage, and scouring of cattle grazing nitrogen-treated plots.

INTRODUCTION

Sulphur has been shown to be of considerable importance in increasing pasture production in Australia and New Zealand (1). Clovers and grasses responded markedly to applications of calcium sulphate with three-fold increase in dry matter yield. Total and inorganic sulphur have been reported to increase in herbage when gypsum was applied to grassland (2). Jones (3) found that when sulphate of ammonia fertilizer was applied to various grass and clover mixtures the sulphur content of the herbage reached maximum values with six and eight cwt. Nitrate nitrogen (4) accumulated in grasses when this fertilizer was used, the nitrate content being detectable at the four cwt. level and considerable at the eight and twelve cwt. levels.

Much work has been done on the effect of fertilizers on the yield, phosphorus and protein content of Irish pastures (5, 6). Little, however, is known of the sulphur status of such pastures and the extent to which it is influenced by manuring. A convenient opportunity presented itself to study this effect when a long-term trial, designed to compare the effects of different levels and types of nitrogen, showed differences in palatability which seemed to coincide with fertilizer treatment. It was decided to pay particular attention to levels of total sulphur and nitrate nitrogen which might possibly have an effect on either the palatability or nutritive value of the herbage.

EXPERIMENTAL METHODS

In 1957 a long-term experiment on the effect of different sources and levels of nitrogen was laid down at Johnstown Castle. The soil was well-drained acid brown earth

(sandy loam to loam texture) derived from mixed shale and quartzite drift. The sward was established by direct re-seeding of a Cockle Park mixture. Plots were 0.4 acre in area and each treatment was replicated five times. Treatments were: 0, 2, 4, 8 and 16 cwt. of fertilizer per acre. One half of each plot received nitrogen as sulphate of ammonia while the other half received calcium ammonium nitrate. Sufficient phosphorus and potassium had been used each year and the nitrogen was applied at different intervals during this experiment. One cwt. of fertilizer was applied to the "2 cwt. plots" (on March 4 and July 7, 1960). The "4," "8" and "16 cwt." plots received 1, 2 and 4 cwt. of fertilizer respectively on four dates (March 4, March 13, June 21 and August 25, 1960).

Swards were stocked with cattle and sheep on a system of rotational grazing. By 1960 plots heavily fertilized with nitrogen consisted of nearly 90 per cent ryegrass while there was still approximately 20 per cent of clover in the control plots (7). Some swards, notably those receiving eight and sixteen cwt. of sulphate of ammonia per acre, were found to be unpalatable, while cattle grazing the plots receiving heavy applications of both forms of nitrogen fertilizer scoured during July and August. Sampling was done (a) before the June 21 application, (b) before the August 25 application of fertilizer, (c) ten days after (b). Immediately after cutting clovers were separated from grasses. Herbage was then dried quickly at 80°C, ground and subsequently analysed for total sulphur (8), sulphate sulphur (9), nitrate (10) and manganese.

RESULTS

Sulphur

It will be seen that sulphate of ammonia fertilizer caused an increase in the sulphur, manganese and nitrate of the herbage (Table I). Calcium ammonium nitrate had no effect on the sulphur content of the herbage. At the final sampling, the plots having received all fertilizers, the total sulphur content increased significantly with sulphate of ammonia application up to the 16 cwt. level. Inorganic sulphur was determined on the samples, and results of the final sampling showed that the inorganic sulphur content of the herbage followed the same pattern as the total content representing 60 per cent of those values (Fig. 1).

Nitrate

The nitrate content of the herbage increased with both forms of fertilizer and at the third sampling the nitrate in the herbage of the 8 and 16 cwt. plots had reached levels regarded by Whitehead (11) as toxic to ruminant animals. Crude protein plotted against nitrate nitrogen gave a pattern similar to that of Griffiths (4) which indicated that grass with protein content above 22 per cent began to accumulate nitrate, and danger levels were reached when herbage contained over 30 per cent protein. Clovers contained very little nitrate.

Manganese

The significant increase in the manganese content of the herbage with sulphate of ammonia treatment was possibly due to the acidifying effect of this fertilizer on the

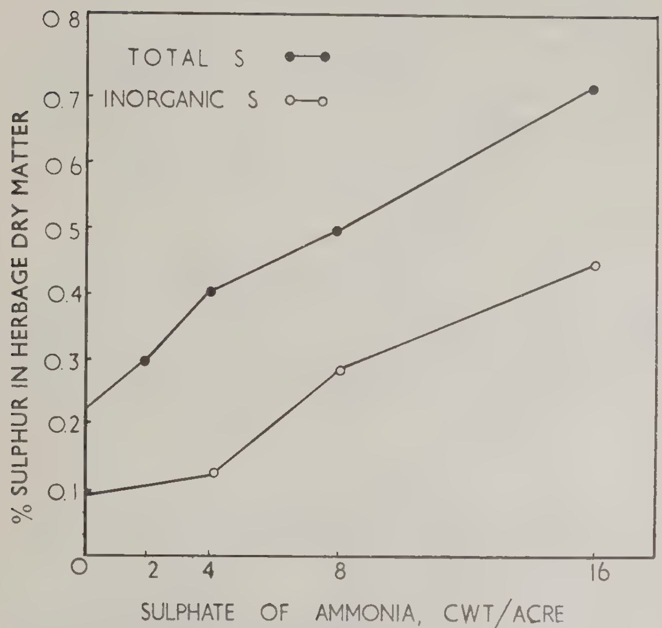


Fig. 1—Effect of increasing applications of ammonium sulphate on the sulphur content of herbage dry matter.

soil. The alkaline reaction of nitrolime would explain the drop in manganese content from the control to the 16 cwt. plots receiving this fertilizer.

DISCUSSION

The sulphur content of the herbage of plots receiving eight and sixteen cwt. of sulphate of ammonia and those receiving heavy dressings of nitrolime might explain the unpalatability problem. The fact that inorganic sulphur compounds are generally unpalatable may support this view as 60 per cent of the total sulphur was in the inorganic form.

The high nitrate content of the herbage on plots heavily fertilized with nitrogen caused no deaths among the stock, but, singly or in combination with the high sulphur content of the herbage it may have been the cause of severe scouring of the cattle grazing those plots. This becomes more apparent when it is realised that the copper and molybdenum levels of the herbage were well within the safe limits, and normal copper values were reported for blood samples taken from some of the stock during the scouring period.

TABLE I

Effect of nitrogen fertilizer on sulphur, nitrate and manganese content of herbage

(Results expressed on dry matter basis)

Treatment (cwt. per acre)	First sampling			Second sampling			Third sampling		
	Sulphur*	Manganese*	Nitrate*	Sulphur	Manganese	Nitrate	Sulphur	Manganese	Nitrate
Calcium ammonium nitrate									
0	0.39	132	0.19	0.40	74	0.14	0.29	110	0.10
2	0.40	120	0.43	0.37	106	0.33	0.25	68	0.28
4	0.41	100	0.13	0.44	66	0.26	0.37	78	0.38
8	0.44	64	0.43	0.38	48	0.22	0.36	64	0.56
16	0.37	92	0.35	0.42	66	0.23	0.31	84	1.69
Sulphate of ammonia									
0	0.38	132	0.19	0.40	74	0.14	0.29	110	0.10
2	0.65	136	0.13	0.58	140	0.25	0.30	140	0.14
4	0.51	146	0.29	0.51	116	0.14	0.41	110	0.17
8	0.63	154	0.46	0.52	128	0.58	0.48	124	0.41
16	0.66	252	0.35	0.51	249	0.45	0.61	210	1.22
Sig. diff. (P=0.05)	0.10	46	0.26	0.23	50	0.37	0.15	34	0.22
(P=0.01)	0.16	73	0.42	0.36	79	0.58	0.25	62	0.34

* = Sulphur and nitrate expressed as per cent., manganese expressed as parts per million (ppm).

The increased manganese levels are scarcely high enough to affect yields but the increase in pH and available manganese of soils with sulphate of ammonia fertilizer may be a factor in establishing clovers as was reported for Australian soil (12).

The increased pasture production from heavy applications of nitrogen are to some extent offset by the complications of reduced palatability and liability to cause scouring.

ACKNOWLEDGEMENTS

The author is indebted to Mr. G. A. Fleming for helpful discussions; to Mr. S. Molloy, Mr. J. C. Brogan, Mr. P. McDonnell for assistance with the chemical analyses and to Mr. M. O'Keeffe for the statistical evaluations. Special thanks are due to the staff of the Grassland Nutrition and Ecology Department without whose co-operation this work would be impossible.

REFERENCES

1. Walker, T. W., *Soils and Fertilizers*, **18**: 185, 1955.
2. Walker, T. W., Adams, A. F. R. and Orchiston, H. D., *Plant and Soil*, **7**: 290, 1956.
3. Jones, D. T. C., *J. Agric. Sci.*, **54**: 188, 1960.
4. Griffith, ap G., *Nature*, **185**: 627, 1960.
5. Sheehy, E. J., O'Donovan, J., Day, W. R. and Curran, S., *J. Dept. Agric. Eire*, **45**: 5, 1945.
6. Curran, S., *ibid.*, **49**: 60, 1946.
7. Maloney, D. and Murphy, W. (private communication).
8. Klober and Howell, *Agric. and Food Chem.*, **6**: 59, 1958.
9. Woodman and Evans, *J. Agric. Sci.*, **23**, 1933.
10. Sorensen, C., *Physiol. Plantarum*, **9**: 304, 1956.
11. Whitehead, E. I., *S. Dakota Farm and Home Res.*, **7**: 70, 1956.
12. Anon., *Rural Res. in CSIRO*, No. 18, 28, 1956.

SOME EFFECTS OF PHOSPHATE FERTILIZER ON LEAF COMPOSITION IN TOMATO

J. G. D. Lamb

An Foras Taluntais, Johntown Castle Agricultural College, Wexford

ABSTRACT

Tomato plants, variety Ware Cross, were grown under four different levels of phosphorus treatment on an acid soil low in available magnesium and having a high fixing power for applied phosphate. As the phosphorus content of the foliage increased that of potassium increased also. These changes were accompanied by a decrease in magnesium and calcium, and by an increase in the nitrogen of the lower leaves.

INTRODUCTION

A common feature of glasshouse soils in Ireland is the prevalence of very high levels of available phosphorus as estimated by extraction with Morgan's solution. These high levels are met each year during the routine analysis of a considerable number of tomato house soils for advisory purposes, e.g. out of 374 topsoil samples analysed during the winter of 1959-'60, 60 per cent were in the "very high" category (over 30 ppm available phosphate). The existence of high levels of available phosphorus in glasshouse soils was also evident in the results of a survey already published (1), where levels of 100 pounds per acre and more of readily available phosphorus were found to be common as compared with *circa* 2 lb. per acre under agricultural conditions. Nevertheless, little information could be found in the literature regarding the possible effects on the tomato plant of such large amounts of phosphorus in the soil, though as long ago as 1927 experiments at Cheshunt indicated that additions of phosphate to the soil caused an increase in the amount of potassium (K_2O) in the foliage (2).

Some data are now presented showing the effects of various phosphate dressings on the composition of tomato foliage, based on fertilizer experiments conducted during 1958 at Johnstown Castle, Wexford.

EXPERIMENTAL

The plants were grown from seed under ordinary commercial conditions, in John Innes seed compost. It is likely that in the propagating stages the plants received at least adequate phosphate. No artificial heating of the house was used during the experiment. The soil in the house was acid (pH 5.1-5.3) with initially a low phosphorus status (3-6 lb. per acre available phosphorus). A tomato crop had been taken from the house in 1957. Basal dressings of potassium were given before planting to maintain the available potassium of the soil at an adequate level (as shown by soil analysis). A light dressing of horticultural peat moss was also given. In addition, all plants received identical continuous feeding with nitrogen and potassium through a trickle irrigation system.

Symptoms of manganese toxicity appeared in subsequent crops of tomatoes grown on this soil, but were not seen during 1958. The phosphorus treatments given were:

(1) Control: (No applied phosphate).

(2) low phosphorus: 2½ oz. per sq. yd. superphosphate (8 per cent P).

(3) medium phosphorus: 6 oz. per sq. yd. superphosphate (8 per cent P).

(4) high phosphorus: 2½ oz. per sq. yd. triple superphosphate (24 per cent P.)

Samples of the lowest six leaves and of the upper leaves were taken at intervals during the season 1958 (Tables II and IV). Before the last sampling two to three of the lower leaves had been removed during the ordinary course of cultural operations. Otherwise the lower leaves sampled were the oldest leaves of the plants. Except on May 19 the second set of six leaves from the base of the plant was not included in the samples.

Each sample was dried at 95°C, ground and mixed. Nitrogen was estimated by a modified Kjeldahl procedure, calcium and potassium by flame-photometric techniques. Phosphorus was estimated by a modification of the method of the Association of Official Agricultural Chemists (3) and magnesium by a modification of Andersson's method (4).

RESULTS

Phosphorus

Taking the results over the season (Table I) the phosphorus fertilizer had a marked effect on the percentage of that element in the foliage. In the lower leaves, such increment of the fertilizer led to a marked increase in leaf phosphorus. In the upper leaves, also, leaf phosphorus increased with increased application of the fertilizer to the soil, though the high dressing had no significant effect over that already attributable to the medium dressing.

TABLE I

Composition of tomato leaves, expressed as percentage of the dried matter (average of all samples)

Treatment	P	Ca	K	Mg	N
Lower Leaves					
Control	0.16	4.78	6.03	0.66	3.58
Low P	0.21	4.50	6.54	0.52	3.74
Medium P	0.26	4.43	7.07	0.53	3.95
High P	0.31	4.08	7.37	0.44	4.04
Sig. diff. (P=0.05)	0.03	0.37	0.45	0.09	0.25
(P=0.01)	0.04	0.49	0.61	0.12	0.34
Upper Leaves					
Control	0.23	3.70	5.39	0.57	4.21
Low P	0.30	3.44	6.17	0.46	4.07
Medium P	0.34	3.69	6.23	0.50	4.55
High P	0.35	2.98	6.58	0.39	4.42
Sig. diff. (P=0.05)	0.04	0.45		0.11	
(P=0.01)	0.06	0.60		0.14	

From Tables II, III and IV it will be seen that at all sampling dates a consistent trend to increasing phosphorus content of the foliage was associated with the increments in soil application of superphosphate. There are indications that the effect decreased during the season. Thus the first increment caused a significant increase in leaf phosphorus at the earliest sampling date, but in the later samplings an increase in phosphorus in the lower leaves is apparent only with the heavier dressings. In the upper leaves a similar weakening of the fertilizer effect with time is noticeable.

TABLE II

Composition of tomato leaves, expressed as percentage of the dried material (average of 5 plants, sampled May 19)

Treatment	P	Ca	K	Mg	N
Lower Leaves					
Control	0.17	2.88	6.20	0.46	3.60
Low P	0.26	2.85	6.35	0.39	4.20
Medium P	0.32	2.85	6.40	0.33	4.25
High P	0.35	2.30	7.20	0.29	4.69
Sig. diff. (P=0.05)	0.08	0.42	0.53	0.06	0.45
(P=0.01)	0.11	0.59	0.75	0.09	0.63
Upper Leaves					
Control	0.27	2.15	—	0.39	4.29†††
Low P	0.44	1.83	6.3†	0.32	5.08††
Medium P	0.51	1.75	6.2††	0.26	5.19
High P	0.49	1.25	6.3†	0.27	5.09††
Sig. diff. (P=0.05)	0.12	0.28	—	0.06	—
(P=0.01)	0.16	0.39	—	0.08	—

† = Average of 4 plants.
†† = Average of 3 plants.
††† = Average of 2 plants.

TABLE III

Composition of tomato leaves, expressed as percentage of the dried material (average of 3 plants, sampled June 18)

Treatment	P	Ca	K	Mg	N
Lower Leaves					
Control	0.17	6.13	5.93	0.77	3.29
Low P	0.20	5.47	7.60	0.48	3.41
Medium P	0.25	5.27	8.60	0.44	3.66
High P	0.33	5.27	7.93	0.46	3.71
Sig. diff. (P=0.05)	0.08	0.92	1.25	0.11	0.53
(P=0.01)	0.11	1.34	1.82	0.16	0.77
Upper Leaves					
Control	0.32	2.13	5.07	0.41	4.64
Low P	0.31	2.07	5.93	0.29	4.63
Medium P	0.32	2.20	6.33	0.29	4.61
High P	0.39	1.80	5.80	0.27	4.40
Sig. diff. (P=0.05)	0.12	0.86	1.68	0.09	0.67
(P=0.01)	0.17	1.25	2.43	0.13	0.96

TABLE IV

Composition of tomato leaves, expressed as percentage of the dried material (average of 5 plants, sampled October 13)

Treatment	P	Ca	K	Mg	N
Lower Leaves					
Control	0.15	5.68	5.94	0.78	3.70
Low P	0.18	5.40	6.16	0.64	3.51
Medium P	0.22	5.32	6.86	0.74	3.84
High P	0.27	4.96	7.24	0.56	3.67
Sig. diff. (P=0.05)	0.04	0.66	0.77	0.19	0.42
(P=0.01)	0.06	0.90	1.06	0.26	0.58
Upper Leaves					
Control	0.16	5.77	5.55	0.81	3.96
Low P	0.17	5.46	6.20	0.66	3.28
Medium P	0.20	6.04	6.20	0.81	3.99
High P	0.22	5.00	7.07	0.54	4.10
Sig. diff. (P=0.05)	0.03	0.68	1.13	0.23	0.27
(P=0.01)	0.04	0.94	1.53	0.31	0.37

Calcium

Associated with these increases in leaf phosphorus there was a tendency towards a reduction in leaf calcium (Fig. 1). Only the high phosphorus plants show a marked reduction in calcium, an effect apparent in both the lower and upper leaves. This effect on calcium was a comparatively weak one (Table II, III and IV). Though the trend was generally consistent, only in some instances was calcium reduced to a

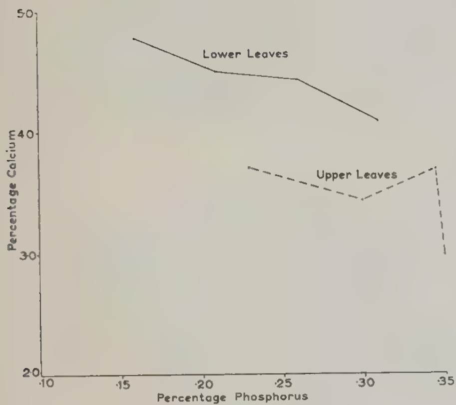


Fig. 1—Relation between phosphorus and calcium in tomato foliage.

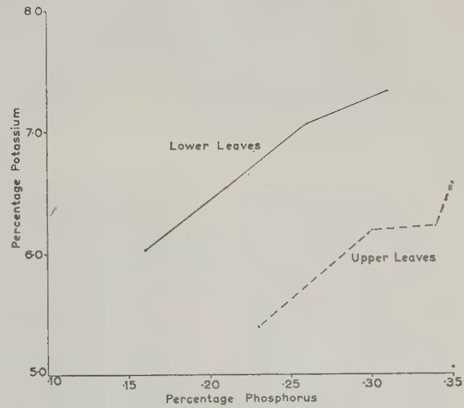


Fig. 2—Relation between phosphorus and potassium in tomato foliage.

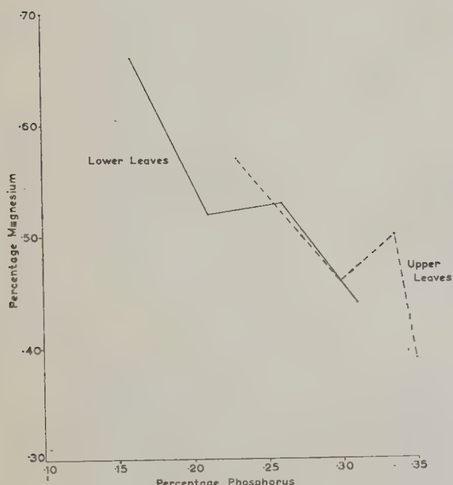


Fig. 3—Relation between phosphorus and magnesium in tomato foliage.

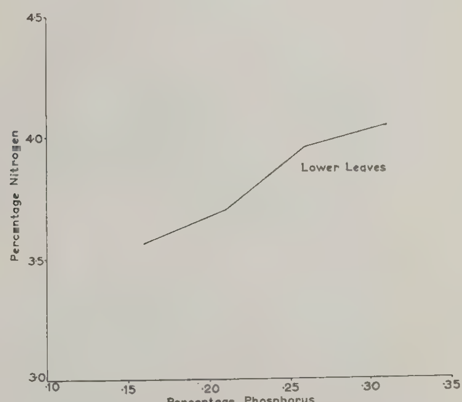


Fig. 4—Relation between phosphorus and nitrogen in the lower foliage of the tomato.

significant degree. In May it required the heaviest application of phosphate to affect the calcium level in the lower leaves. In the upper leaves the effect was more marked, for the low phosphorus plants showed a decrease, further accentuated where the high phosphate treatment had been given. In the June samples the trend to lower calcium could not be proved significant, but in October leaf calcium was again markedly reduced in both upper and lower leaves where the superphosphate had been given at the highest rate.

Potassium

It will be seen that, taking the season as a whole, as the phosphate content of the lower leaves increased, the percentage potassium increased also (Fig. 2). Although in May the high rate of application of phosphate was necessary to effect a significant increase in leaf potassium, the low rate was sufficient to establish significance in the June samples and the medium rate in those taken in October (Table IV).

In the upper leaves, also, an overall trend to higher potassium with high phosphate could be traced, though the data available were only sufficient to prove this in the samples taken from the high phosphate plants in October.

Magnesium

The increased phosphate application reduced the magnesium content of the foliage, as shown for the season as a whole in Fig. 3. This effect was comparatively marked (Tables II, III and IV). Thus, in May the low and medium phosphate plants showed a progressive decrease in both the lower and upper foliage with at least a trend to further reduction in the lower leaves of the high phosphate plants. In June the lowest application of phosphate was still sufficient to reduce the magnesium content of all the foliage, but by October only the high phosphate plants showed a definite reduction, this reduction still being evident in both upper and lower foliage.

The reduction of the magnesium content of the foliage by application of superphosphate was accompanied by the appearance of visible symptoms of magnesium deficiency. In September, out of sixty-four plants in the high phosphate treatment, forty-nine were obviously affected. Of forty medium phosphate plants, eleven showed symptoms, but only one plant was visibly affected out of forty plants which had not received superphosphate.

Nitrogen

In general the nitrogen content of the lower leaves rose as the phosphate content rose (Fig. 4). While at the May sampling there was a marked increase in the nitrogen content of the lower foliage of the plant with greater application of phosphate, this effect was less marked later in the season. Thus, in June a trend to higher nitrogen still persisted in the lower leaves but was not found in the October samples. The nitrogen levels in the upper leaves did not show significant differences associated with the phosphate treatments.

Yield

The average yield per plant under the different treatments is given in Table V. The yield tended to increase with increasing phosphate, but only the difference between the yield of the high phosphate plants and the control plants was statistically significant.

TABLE V

Total weight of fruit picked per plant*
(average of 7 plants per treatment)

Treatment	Crop
No P	5.24 lb.
Low P	5.70 lb.
Medium P	6.66 lb.
High P	7.46 lb.
Least significant difference (5 percent)=1.5	
(1 percent)=2.06	

* = up to October 13.

DISCUSSION

The increase in leaf potassium following on increased application of phosphate fertiliser to the soil is in agreement with the results reported by Owen at Cheshunt (2). The decrease in magnesium and calcium may be explained as secondary effects following on the increase in leaf potassium rather than being directly attributable to the increased application of phosphate.

Walsh and Clarke (5) noted that one factor in depressing the content of magnesium in tomato leaves was the sulphur present in the sulphate radicle of fertilisers, but in the experiments described in this paper even where phosphate was applied in the form of sulphate-free triple superphosphate, magnesium was reduced. Nor can the effects associated with increased phosphate application be explained satisfactorily as being due to increased yield. Only in the high phosphate plants is there a significant increase in yield (significant only at the 5 per cent level by the variance ratio test), and in any case many of the effects occurred at the lower rates of application. Analysis of yields in relation to foliage composition showed no significant degree of correlation. Positive correlation could be established, however, between phosphorus and potassium in the lower leaves (significant at the 1 per cent level), and negative correlation between phosphorus and magnesium. By this test also the effect of phosphorus in reducing leaf calcium proved weak, the negative correlation proving significant at the 5 per cent level. Only a trend could be traced between phosphorus and nitrogen.

These plants were grown on an acid soil low in magnesium and with a high fixing power for phosphate. It remains to be determined how far the effects described are a factor in the prevalence of magnesium deficiency in plants grown on soils rendered

highly alkaline and very high in available phosphates by the usual practice of heavy applications of farmyard manure, superphosphate and often lime as well. Though Walsh and Clarke (5) have shown that the main cause of such deficiency, occurring even in soils of high magnesium content, was an excess of potassium, the results described above suggest that the very high levels of available phosphate may have an accentuating effect.

ACKNOWLEDGEMENTS

The advice and encouragement of Dr. T. Walsh are gratefully acknowledged. Thanks are due to Mr. J. C. Brogan and the staff of the Soil Laboratory, Johnstown Castle, Wexford, for the soil and plant analyses, and also to Mr. M. O'Keeffe for the statistical analyses. The plants were grown and cared for by Mr. J. Dwyer, who gave valuable assistance with the sampling and recording.

REFERENCES

1. Lamb, J. G. D., *J. Dept. Agric. Eire*, **50**: 129, 1953-4.
2. Owen, O., Cheshunt Exptl. Res. Station, 15th Annual Rep., 1929.
3. Assoc. Official Agric. Chemists, "*Official Methods of Analysis*," Washington, D.C., 8th Ed., 1955.
4. Andersson, K. G. Kawe, *Anal. Chem.*, **24**: 1029, 1952.
5. Walsh, T. and Clarke, E. J., *Proc. Roy. Irish Acad.*, **50 (B)**: No. 13, 245, 1944.

Communication to the Editor

COPPER AND NITROGEN IN THE NUTRITION OF WHEAT ON CUTAWAY PEAT

Abstract. Copper deficiency in wheat grown on cutaway peat was accentuated following nitrogenous fertilization. Residual effect of copper sulphate dressings as low as 7 lb. per acre was sufficient to ensure good growth.

Experimental work on cereals growing on cutaway peat was carried out at the Peatland Experimental Station, Derrybrennan, Co. Kildare in 1959 as part of an experimental programme designed to investigate the agricultural potentialities of cutaway peat.

The site of this experiment had been treated in 1957 with the following rates of copper sulphate ($5H_2O$), 0, 7, 14, 28 and 56 lb. per acre. In April 1959, Atle wheat was combine drilled with 4 cwt. per acre of 8-8-16 granulated compound. In May, a calcium ammonium nitrate top-dressing was applied to each copper treatment at the rates of 0, 2 and 4 cwt. per acre. There were three replications of each treatment.

Observations throughout the growing season brought to light the following points:

(*a*) Plots receiving 4 cwt. nitrogenous fertilizer and no copper, failed completely. Plots receiving 2 cwt. of nitrogenous fertilizer and no copper grew to a stage where ear development was just perceptible. Plots receiving no nitrogen and no copper produced grain, but on a very restricted scale. At the braird stage all plots receiving no copper showed typical copper deficiency symptoms, increasing in severity with increased nitrogen treatment.

(*b*) All plots receiving the varying copper treatments plus 4 cwt. of nitrogenous fertilizer developed normally and no difference was apparent between the different copper treatments.

(*c*) Plots receiving no nitrogen showed symptoms of nitrogen deficiency in all copper treatments. This effect was also noticeable but to a lesser degree in plots receiving 2 cwt. of nitrogenous fertilizer.

The effect of nitrogen on copper uptake has been observed by other workers. Mulder (1) noted a relationship between copper and nitrogen nutrition of wheat in pot experiments and concluded that increasing nitrogen dressings required increasing copper application in order to maintain normal plant growth. Brown and Harmer (2), using high organic soil from Michigan, carried out greenhouse studies on the influence of different copper compounds on the yield and composition of wheat and corn. These workers noted that when copper was not applied, the wheat grew better without fertilizer. Where copper alone was applied some improvement was noticed and where

copper plus fertilizer was applied, marked improvement was apparent. They concluded that the application of fertilizer without copper accentuated copper deficiency. Voisin (3) has also stressed the importance of copper application to pastures where relatively large amounts of nitrogen are being applied.

Copper and nitrogen interaction has not previously been reported under Irish field conditions. The work at Derrybrennan draws attention to the importance of this interaction in the nutrition of one crop. The extent to which it may apply to others is obviously worthy of further investigation.

Garrett A. Fleming
An Foras Taluntais, Soils Division, Johnstown Castle, Wexford.

(the late) J. Delaney
An Foras Taluntais, Peatland Experimental Station, Derrybrennan, Co. Kildare.

REFERENCES

1. Mulder, E. C., *in* "Trace Elements in Plant Physiology," Chronica Botanica Co., Waltham, Mass., 1950.
2. Brown, J. C. and Harmer, P. M., *Soil Sci. Soc. Amer. Proc.*, **15**: 284.
3. Voisin, A., "Soil, Grass and Cancer," Crosby, Lockwood, London, 1959.